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ABSTRACT

The goal of this conference was not exchange of information, but rather, identification of the decisions that should be made by higher education, industry, and government to facilitate the valid growth of the instructional use of the computer. Four major questions concerned the conferees: What will be the computer's capabilities and cost? How will computer services be provided to the campus? How will instructional materials be provided? and How will higher education be affected by instructional computer use? The reports of the conference sessions are divided into three sections; first, discussions of the range of possible answers to the major questions; second, reports on the recommendations developed by the several studies of instructional computer use that are currently under way or have been recently completed; and third, specific recommendations for higher education, industry, and government. (JY)

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Proceedings of A Conference held October 1970

Roger E. Levien, Editor

A Report prepared for

NATIONAL SCIENCE FOUNDATION
AND
CARNEGIE COMMISSION ON HIGHER EDUCATION

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ACKNOWLEDGMENT

It is difficult to appreciate the amount of work that must be done to organize and run a conference and to produce its proceedings until one has been part of such an activity. Indeed, the greatest success may be said to have been achieved when, to those who have not had a hand in organizing it, the conference seems to occur smoothly and effortlessly. Only those deeply engaged in its organization are aware of the hundreds of letters, phone calls, visits, arrangements, and rearrangements, last-minute changes and emergencies that must be handled to bring 150 people together for a productive three-day conference. And only those who have observed the process closely can appreciate the attention to detail that is essential to its success.

This conference and these proceedings have benefited enormously from the diligent, skillful, and cheerful labors of five persons who handled the myriad organizational, managerial, and production tasks with high competence and unfailing energy. Jean Scully oversaw the conference arrangements from compiling mailing lists, to renting the facilities and assuring the conference's smooth progress, to distribution of these proceedings. Maureen Madden worked closely with Jean on the arrangements and in the management of the conference's daily affairs. Bernadette Lewis was responsible for the visual design of the conference publications, but her talent and taste contributed to many of the other decisions as well. Janet Murphy DeLand (with the assistance of Laurel Rottura and Pat Bedrosian) and Beverly Westlund have guided the editorial production of these proceedings and other conference publications from author's manuscript to printer's typescript.

INTRODUCTION

On October 1-3, 1970, The Rand Corporation held a conference on *Computers in Instruction: Their Future for Higher Education,* attended by 150 individuals from higher education, industry, and government whose activities or responsibilities give them influence over the future development of instructional computer use. The conference was sponsored by the National Science Foundation, the Carnegie Commission on Higher Education, and The Rand Corporation.

There have been numerous conferences on computer use in instruction; several were held during the summer of 1970, immediately preceding this conference. But those conferences were primarily concerned with the technology and technique of instructional computer use and served principally to facilitate the exchange of information among computer scientists and educators actively engaged in the development of computer-based instructional materials. In distinction, this conference paid little attention to the details of instructional technology and technique. Rather, it began with the assumption that there are already many valid uses of the computer as an instructional tool and that the number and range of *potential* uses will expand as computer costs recede and computer capabilities advance and as experience with the computer in instruction grows. The starting point of the conference was recognition that the rate of growth of *actual* instructional computer uses and their introduction in the over 2500 institutions of higher education will not be determined principally by the rate of advance of the instructional computing state of the art, but rather by the institutional context within which instructional use will occur. The central questions are: How will computer service be provided? Who will pay for it? Who will develop instructional materials? How will those materials be distributed? How will instruction be provided? Who will prescribe, monitor, and evaluate instructional activities? The answers to these questions will shape the future of actual instructional use of the computer. Thus, the conference focused attention on the instructional framework within which instructional uses of the computer must develop. The goal was not exchange of information but rather identification of the decisions that should be made by higher education, industry, and government to facilitate the valid growth of instructional use of the computer.

With that objective in mind, the conference was divided into three sections. During the first section, the major questions were presented and a range of possible answers to each one was described. The second section comprised reports on the recommendations developed by the several studies of instructional computer use that are currently under way or have recently been completed. The third section engaged the participants in three workshops to develop specific recommendations (based on their own experience and the conference discussions) for higher education, industry, and government.

Section One of the conference addressed four major questions in four sessions.

The first session considered the question: *What will be the computer's capabilities and costs?* Its purpose was to establish the technological context for the institutional considerations of the remainder of the conference. The first two papers looked into the future of computer technology in general. Carl Hammer of Univac described the prospects for computer hardware development. Robert Spinrad of Xerox Data Systems examined the likely future trends in computer software. The second two papers narrowed the focus to technological developments that will directly serve instructional computer use. They described the two major trends in computer systems for instruction: large, centralized systems and small, decentralized systems. Donald Bitzer of the University of Illinois reported on the design of PLATO IV, which will serve 4000 instructional terminals from a single large computer, housed centrally. Kenneth Stetten of The MITRE Corporation discussed the design of TICCET, which will serve up to a few hundred instructional terminals from a single small computer, housed at the site of instruction. At the conclusion of the session, Fred Tonge of the University of California-Irvine, and Harry Huskey of the University of California-Santa Cruz, commented on these projections from their perspectives as university-based computer scientists actively engaged in instructional computer use.

The second session considered the question: *How will computer services be provided to the campus?* The means by which computer service is provided directly affects the ease with which instructional materials may be developed, distributed, and employed, yet decisions about computer service on individual campuses rarely take such considerations into account. The purpose of this session was to explore the interaction between provision of computer service and instructional computer use and to determine which of the several alternatives satisfied the needs of instruction. Four major alternatives were described, each by an advocate of its benefits. William Kehl of U.C.L.A. advocated centralized campus facilities (unfortunately, his paper was not available for these proceedings); Peter Lykos of the Illinois Institute of Technology supported a system in which decentralized campus facilities would play a major role; Gerard Weeg of the University of Iowa described the advantages of regional computer networks providing service to a number of institutions; and Clint deGabrielle of the Computer Education Institution, Inc. urged a role for commercial time-sharing services. At the conclusion of the session, John Hamblen of the Southern Regional Education Board and Dan Burgess of Control Data Corporation contributed their reactions to the speakers' advocacies.

The third session turned to the central issue: *How will instructional materials be provided?* The computer becomes an effective instructional tool only through programs, which must be written, tested, refined, packaged, marketed, distributed, and serviced. At present, authorship is generally carried out by a local faculty member and the remaining functions are performed haphazardly or not at all. Growth in instructional computer use depends critically on developing effective institutions to carry out each of those roles. There are several possibilities. This session contained presentations by advocates of four major alternatives. Harold

Mitzel of Pennsylvania State University argued for nonprofit consortia formed by developers and users of computer-based instruction. Robert Seidel of the Human Resources Research Organization (HumRRO) urged the use of special development organizations set up and staffed particularly to create and distribute computer-based instructional materials. Ronald Blum of the Commission on College Physics advocated the development of instructional materials by discipline-based groups. David Engler of McGraw-Hill saw the publishers playing a role for computer-based materials similar to that they have played in the textbook field. Reactions to these points of view were given by H. A. Wilson of Harcourt Brace Jovanovich, Inc., William Schneerer of Case-Western Reserve University, and Lawrence Stolurow of Harvard University.

The fourth session presented a variety of views concerning: *How will higher education be affected by instructional computer use?* William Pounds of the Sloan School of Management, M.I.T., painted a picture of modest, though useful, effect. Edward Lambe of the State University of New York at Stony Brook foresaw somewhat greater effect, but only after slow and difficult development efforts, especially with regard to methods of instruction. Daniel Alpert of the University of Illinois saw the potential for computer-based education to become an effective and efficient means of meeting the unmet needs of education and of increasing its quantity and quality. He viewed the computer as a powerful tool for innovation in curricula and institutions. Robert Tschirgi of the University of California-San Diego anticipated that the effect of computers on education would be "enormous," leading to the geographic dispersal of the campus, redefinition of the roles of student and professor, greater interdependence among educational institutions and between them and the non-academic community. He sketched a computer-based academic revolution. This spectrum of views, from conservative to revolutionary, was reviewed and commented upon by John Caffrey of the American Council on Education, Henry Chauncey of the Interuniversity Communication Council, Inc. (EDUCOM), and Raymond Stith of The Junior College District of St. Louis.

Section Two of the conference reviewed the policy recommendations that had been developed by the five studies under way or recently completed concerned with instructional uses of the computer. Karl Zinn of the University of Michigan reported the findings of his Project CLUE (Computer Learning Under Evaluation), which received financial support from the U.S. Office of Education. Sterling McMurrin of the University of Utah summarized the relevant conclusions of the Commission on Instruction Technology, of which he had been chairman. The Commission, authorized by the Public Broadcasting Act of 1967, called for establishment of the National Institutes of Education, one of which would be a National Institute of Instructional Technology. John Whinnery of the University of California-Berkeley described the conclusions of an assessment of instructional technology carried out by a committee on Instructional Technology of the Commission on Education of the National Academy of Engineering. M. S. Scott Morton of the Sloan School of Management, M.I.T., presented a progress report of a study on the Impact of Technology on Higher Education sponsored by the Carnegie Commission on Higher Education and The Ford Foundation. Roger Levien summarized the findings of Rand's study of instructional uses of the computer in higher education sponsored by the Carnegie Commission on Higher Education and the National Science Foundation.

Section Three of the conference provided the conferees an opportunity to draw upon what they had heard at the conference and their own experience and attitudes to derive recommendations for action by higher education, industry, and government. Three working groups were formed for this purpose; each produced a statement of recommendations.

After the conference dinner, Theodor Nelson of The Nelson Organization, Inc., described a vision of what the computer's use in instruction might become, if only we could see beyond the "trivial horizons" of most computer people to the prospects of an "entire cultural revolution based on computer display."

These proceedings contain the papers presented at the conference, the comments made by the discussants and members of the audience, and the reports of the conference workshops. Two papers submitted by conference attendees, Roulette Smith of the University of California-Santa Barbara and John Hamblen of the Southern Regional Education Board, have also been included because of their prospective interest to those who read these proceedings.

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SECTION ONE

Session I

WHAT WILL BE THE COMPUTER'S CAPABILITIES AND COSTS?

Barry W. Boehm, Chairman

THE FUTURE: INTERACTIVE ELECTRONIC SYSTEMS

Carl Hammer
Computer Sciences, Univac, Washington, D.C.

Scientists the world over are facing an awesome responsibility as their work brings them ever closer to the point where drastic and possibly irreversible changes in our earthly environment are taking effect. Some of these alterations, such as in the temperature of our atmosphere or of the oceans, result from the increasing pollution which our engineering technology produces. Other changes could result from planned experiments of a global nature; these might include redistribution of the water on the surface of the earth, or an attempt to control weather and climate over cities and even continents.

The solution of these and other problems of similar magnitude will require the application of electronic computer systems to a degree which by far exceeds their seemingly miraculous powers of today. Scarcely two hundred years ago, the Swiss mathematician Leonhard Euler completed his calculation of π to 600 decimals and concluded this Herculean effort with the laconic remark that "it would be impossible" to extend this computation further because of the excessive amount of manpower needed. He made this statement on the basis of the technology known to him in his own time. Yet, in the past twenty years we have computed π first to 2,000, then to 10,000, and finally to 100,000 decimals!

For the record, the last computation took less than eight hours on one of our electronic brains, while "uncle" Euler toiled for two years to finish his work by hand. Therefore, let us beware of attaching the label of impossibility to achievements whose implementation we can not readily foresee! After all, space travel, atomic energy, color television, and global communications, to mention just a few, were unheard of only fifty years ago but they are now an integral part of our everyday life.

The role which electronic systems hardware has played in making these accomplishments come true is basic to our understanding of the future which mankind is about to face. In order to better see the course which our electronic engineers are helping us chart, it is desirable that we take an analytical look at the past and then extrapolate forward in time.

We shall first single out man's early engineering activities which were predominantly concerned with making tools to augment his "muscle." Developments in that area are still continuing with the design of larger engines, machines, and devices to provide man with a mechanical advantage over nature—or himself. With the invention of the automobile, for example, man increased his mobility by a factor of at least one hundred; the airplane bought him another order of magnitude. Similarly, man's innate desire to conquer and control his environment gave him a leverage of about three orders of magnitude in every other area to which he applied his inventive genius. However, the laws of physics and mechanics will prevail and it is thus quite unlikely that terrestrial transportation will ever proceed at speeds approaching those which are theoretically feasible in outer space. But even the most fantastic astronautical velocities do not exceed those that walking man can maintain by more than six orders of magnitude.

During the late thirties it became apparent that man's voracious appetite for computing power would have to be satisfied in a better way than by the then-best-available electromechanical calculators. It was also evident that such machines would have to store their own programs, or "computing recipes," so as to achieve greater speeds than could be maintained by interaction of human operators and electromechanical computers. Thus was born, in the mind of John von Neumann, the concept of the program-stored machine, the electronic computer of today. Moreover, this machine, designed to augment his mind, gave man almost at once a leverage factor of ten thousand (with the invention of the ENIAC) and today's super-computers provide us with an advantage of one billion to one. But we note with awe that the seemingly miraculous accomplishments of today will soon be dwarfed by new designs already on the drawing board!

We all know that the introduction of electronic computers, and more recently that of large electronic systems, has already caused profound changes in the structure and organization of our society. Large-scale business data-processing without the aid of these machines has become unthinkable. Real-time systems and time-sharing make the power of the computer available to untold thousands at their desks and even in their homes. Global networks exist now which provide message and circuit-switching services to an exponentially expanding circle of users. And yet, this is only the beginning; the real impact of electronic systems upon human society and the way it is structured will continue to make itself felt for decades!

Not too long ago, we completed a study to determine where future electronic systems technology will take us. Our "Technology Forecast" began with the establishment of a structured data base, using the "Delphi" technique. We asked a large number of people, intimately associated with our field, what events they thought were likely to occur any time in the future. These events were then catalogued and our scientists affixed probable dates to them. Next, we obtained a statistical distribution for these dates and also determined which events had to occur prior to others. The last step is similar to the well-known management tools of PERT (Program Evaluation Review Technique) and CPM (Critical Path Method).

This study had a data base of almost one thousand events. They cover the general spectrum of systems, as well as many categories of special devices, circuits, modules, hardware in general, software, and even brainware. Our study was not planned to go beyond the electronic state-of-the-art technology; for instance, it did not address itself to the social impact which these developments might have. These aspects are sometimes lumped together under the heading of "Cybernetics" and we shall discuss them shortly. In the area of engineering technology, however, it was agreed that there will be "no surprises." The so-called breakthroughs are actually long-range developments which go through the stages of invention and innovation in a predictable manner. Cost-performance ratios tend to improve only slowly, allowing for an orderly growth process within industry and economy. In fact, if someone could design, develop, and manufacture one of our electronic supercomputers for one dollar, he would have the market cornered in no time. On the other hand, the same device would never "sell" for a billion dollars and its true value is established by our competitive technology openly and within the market place.

To give you a flavor of the things to come, and to establish a basis for discussion, we have singled out a few of the events for your consideration:

1. A system of national and international technical data banks will be created; it will be operational by 1980. Managers of large corporations and government agencies will have access to it via their own electronic systems; by 1985 most individual scientists will access this system through desk-top devices; by 1990 it will even provide electronic language-translation capabilities on an international scale.
2. Laboratories, as we know them today, may go out of style by 1993, as experimentation by computer simulation will be less expensive and more reliable. Laboratories will then only be used to validate the research done "on the computer."
3. Office and home use of computer utilities centralized on a city-wide basis will be fully accepted by 1985.
4. Advanced communication terminals, including graphics and some form of voice input and output, will allow many managers and professionals by 1985 to carry on their work at home, eliminating most person-to-person contacts and commuting travel as well.
5. Post Office services as we know them today will be almost nonexistent by 1987; they will be replaced by point-to-point digital transmission of data and information.
6. The acceptance and use of a Universal Personal Identification Code (UPIC) for the unique identification of individuals will occur about 1980. This code, likely in the form of "voice-prints" will herald the era of a cashless and checkless society in which individuals can even be called upon to vote in "real-time" if the occasion demands it.
7. Microelectronic and medical technologies will reach a point, likely by 2050, where it will be possible to directly stimulate (by implantation or other means) the appropriate areas of the human brain in order to produce sights and sounds as an aid to the blind and deaf.
8. Cost per operation in electronic computers will drop from current levels by a factor of 200 by 1978.
9. A significant increase in the use of small computers suitable for procurement by individuals will take place by 1980; they will perform such functions as climate and lighting control in homes and offices, systematic information retrieval from various sources such as stockbrokers, banks, and retailers, and scheduling of such functions as maintenance, budgeting, and medical care.

10. Three-dimensional color replication of living and moving objects will be technically feasible by 1981; requiring only optical devices for "sensing" by the viewer.

11. Speech-recognition devices capable of identifying dozens of speakers using the system will be available by 1983; by 2050 computers will accept spoken input and produce audio output employing the extent of vocabulary and idiomatic usage as does an educated person.

12. By 1972 man-machine interactive capabilities will allow a user to examine in great detail, at various levels, and in real-time, the output results of management information reports. With this event will come the opportunity to experiment, through simulation, with overall results and plans by causing changes in variables used in projecting from the established basis and this stored information. As a result, there will accrue a greater understanding by the managerial user of the scientific methods employed to derive this information and of the effects which changes in certain variables will have in selected areas.

Notice that our list is limited to electronic engineering; it does not include predictions about accomplishments in other fields. For example, it does not reference the relatively new field of bionics, where people begin to think about the possibility that man could indeed create life and artificial intelligence. Perhaps the significance of Woehler's first organic synthesis (1826) will take on added meaning when we first create living organisms, possibly before the end of this century. What will man do then with his knowledge? Will he create a better world for himself and his heirs? Or does there exist a built-in mechanism in our species, directing us toward self-destruction and ultimate extinction?

The world of today is in a state of gross unrest, as evidenced by riots, wars, and economic upheavals everywhere. In the west, philosophers have created many magificent fictions of perfection, beginning with Plato's *Republic,* through More's *Utopia,* Rapp's *New Harmony,* and Skinner's *Walden Two.* More recently, however, our military and political leaders have created nothing but tragic realities of imperfection. Until recently, these were but small perturbations perpetrated on an unheeding and unknowledgeable ecology. However, man's aggressions and his pollutions may constitute first-order threats to his continued existence. In their desperation, our leaders are now turning to science hoping to discover a new road to the old destination of peace and tranquility.

Scientists are of the opinion that no Utopian culture is viable. But what can we say about cybernetic cultures of the type now envisioned and made possible by advances in the electronic state of the art? We may wish to compare these two types of cultures, trying to extract from historical normative societies, psychology, management theory, and sociology necessary or sufficient constraints which appear to apply to all cybernetic cultures.

Cybernetics has been defined as the science of information-processing, communication, and optimal control in complex, purposive, dynamically stable systems whose human elements provide feedback in a specified environment. While a culture, in general, is a complex self-organizing system, cybernetic cultures will be characterized by the introduction of optimizing control mechanisms which react to slowly changing values so as to produce dynamic stability. Engineers tend to think that the mere injection of computers and electronic systems into our society will produce these optimal controls. However, cyberneticists believe that the computer in itself is merely another means of gaining leverage over nature; they know that it is not really endowed with artifical intelligence! Rather, the process of optimization which will transform our separate cultures into a cybernetic society requires the hardware and software of today's computers and also the brainware supplied by their human masters. It takes very little introspection to see that we will never be able to ascribe infinite wisdom to electronic systems, no matter how complex they are; in fact, we do not even expect such performance from human beings! Advanced electronic systems now under design begin to resemble the better known hierarchical, self-organizing, organic systems with which we are more familiar. Each level in the system's hierarchy tends to optimize its own operations: The living cell struggles for life in ignorance of other cells which constitute a living body; the body fights for food, space, light, and gratification of various pleasures in competition with other bodies; the species and organized societies comprised of such bodies exhibit similar tendencies on an even larger temporal and spatial scale. In the end, cosmologists are beginning to establish the same principle of hierarchical subsystem operation and optimization for solar systems, galaxies, and the universe.

Thus we must understand that we are in the midst of a transition from an automated to a cybernetic society. By the end of this century, electronic systems will affect or control practically every aspect of human endeavor. Every person will have then at his or her disposal a vast complex of computer services. Information utilities and data banks, for example, will make computer power available to the public in the same way that electric or other utilities today service our homes and offices. High-speed communications systems, on a global basis, will transmit data and messages almost instantaneously between any two points on earth or of colonized space. Government officials, businessmen, scientists, students, even housewives and children will "converse" with computers as readily as they now talk by telephone.

The advances in the state of the art have been rapid and they have given rise to many controversies. One of them, of interest in this connection is the argument of robots versus integrated systems, with or without man in the feedback loop. For example, is it more desirable to develop completely integrated systems for outer-space probes or should we emphasize manned space-flight ventures? The former approach has the advantages of engineering compactness; it eliminates the need to provide artificially maintained atmospheres and living conditions for human beings. The latter approach claims that steersmanship and human decision-making processes are necessary because computers cannot yet be programmed to cope with the spectrum of all possible eventualities. The events of Apollo 11 and Luna 15 offer testimony which is hard to ignore! There is much to be said for and against either approach; however, there is little doubt that manned space travel will never be completely replaced by unmanned probes or teleoperated controls.

Generally, man is still very reluctant to entrust his fate to a machine. But as we perfect the decision-making models, more and more of the real-time processes in our society will be turned over to the machine for monitoring, reporting, and control. In most instances these models, especially in the fields of economics, planning, and scheduling, are still rudimentary. But there can be no doubt that we will improve them to a point where their power or artifical intelligence will at least equal that of their human masters. Certainly the speed with which the machine can react already exceeds by far man's own response time. Soon we will begin to experiment with more sophisticated models and their ultimate adoption, even in economic process control, by the turn of the century seems certain.

The very structure of our society will thus change under the impact of these developments. The introduction of a universal personal identification code, mentioned earlier, may soon eliminate largely the need for physical money and usher in the much-publicized cashless and checkless society. Elaborate and universal display apparatus located in our homes will permit an untold number to "be on the job" without having to commute to offices and other places of business, thereby making travel either a matter of pleasure or of dire emergency. The very same devices will be used to display newspapers, books, or learning materials, and they may well put the stamp of obsolescence on all printed matter—or let us hope, at least on all junk mail. Computer-aided training, instruction, and education will become commonplace where it is the exception now, affording everyone the advantages of higher learning.

Some day soon, electronic systems are certain to take over practically all the tasks of rote and drudgery which nature and society now impose upon us. Therefore, man must set higher goals for himself technically, politically, and psychologically or run the risk of economic and technological enslavement. It will take all of our ability, energy, and resolve to make certain that we remain masters of our own fate in the coming of this cybernetic culture. The outlook is indeed very bright if we just learn how to make intelligent use of our not-always-so-intelligent and often-maligned machines.

DEVELOPMENTS IN COMPUTER SOFTWARE

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INTRODUCTION

The title assigned me for this talk is "Developments in Computer Software." As is almost traditional on such occasions, I find that I must start by reminding you that what the conference organizers hoped would be a reasonably neat, packageable topic is really not that. (We, each of us, see richness and detail in our own work, while others, looking from afar, see a simpler, less intricate subject.)

"Software," like "hardware," is a generic term. It is, broadly speaking, that which—with the hardware—gets the job done.

One can, however, distinguish three classes of software: application programs, languages, and operating systems.

Operating systems organize and tender the services of the hardware to other programs. (They act the role of the "middlemen" between the equipment and the application program.) The application program solves a particular problem or provides a required service. Computer languages, of course, are the medium in which the problem solution is expressed.

Though these are all "software" they are as different from one another as a radio is from a display screen is from a garage door opener—all these being "electronic."

What, then, is the status of these three classes of software?

APPLICATION PROGRAMS

The promise of the sixties—that problem-solving programs would be broadly generalizable—has, I think, not been realized. It is rare that an application program, plucked from a users group library, is used, unmodified, by another.

The reasons for this are not clear. Perhaps our work and our problems are more particularized than was at first thought. Or, on the other hand, maybe there are applications which could be handled in a standardized way but for the "N.I.H. factor" or for the propensity of humans to "tinker" with something they get in order to make it "better."

Whatever the reason, it is true that what I might call "similar" problems are solved independently and repetitively all over the United States. There are, of course, exceptions. There is, for example, substantial commonality in a number of banking applications.

Let me emphasize that I am, here, lamenting the infrequent transfer of actual programs. In contrast, techniques of problem solution (algorithms) do, I believe, spread effectively through the concerned technical and professional groups (e.g., the fast Fourier transform techniques).

LANGUAGES AND THEIR COMPILERS

In my judgment, computer languages and the technology that surrounds them are in better shape than other software areas. (This is a comparative dgment only. "Chaotic" is still a fair description of the whole field.)

However, the "established" languages are just that—established, accepted, well-understood, and buttressed with a solid base in the technology. New languages, when they falter (which they often do), rarely do so because of intrinsic technical inadequacy. Rather, it is because they are not different enough to "buck" the enormous momentum (technical and financial) of a "standard."

Nevertheless, new (and needed) specialized languages continue to be successfully introduced. Compiler-compilers are becoming better understood and more effectively used.

I think languages have grown pretty much as expected.

OPERATING SYSTEMS

Operating systems present a different picture. They grow larger, more involuted, and more obtuse—seemingly without bound. In this area more than any other, the fulfillment rarely matches the desire (or the promise).

I think one can discern the reason for this in the widening gap between the possible and the actual. We are, after all, just in the earliest stages this new science. (The Computer Era is, at best, two decades old.) As a consequence we are still skimming the cream off the top of a rich pitcher of opportunity.

Turing showed us that almost anything is possible with a computer and we are falling over one another in the rush to prove him right. New services, new data structures, new retrieval techniques, resource sharing, multiprogramming, dynamic reconfiguration—a hundred notions, valid and worthwhile—pour from the minds of the theorists into the IN basket of the programmer. They should have gone to the system designer (or architect), but they didn't. Each new idea was, after all, just a small addition or a slight restructuring of an existing system—and those things were always done in *soft*ware.

Software got its name because it was soft, and malleable—unlike hardware which was unchangeable.

So operating systems grew—continually adding new features to a rickety structure never meant to support them, by a process that can best be described as applied ad-hoc-ery.

Most operating systems today exhibit the symptoms of this Topsy-like growth. They are hard to maintain, hard to change, and hard to understand. Yet, in the evolution of every one of them there were times when, prior to embarking on a new set of extensions, the question of a new start was raised. Only rarely was the answer affirmative. Each enhancement seemed justified on the basis of continuity, prior investment, timeliness, and expediency.

However, I believe that the camel's-back argument obtains here. Continually extended operating systems finally reach a point where the next addition—no matter how cleverly inserted—yields a net loss in performance. Then, instead of the programmer having a tiger by the tail, he has a dinosaur.

What then? Let me first identify some other trends that are further influencing the situation.

TRENDS IN INFORMATION SYSTEMS

A major phenomenon in the computer industry is the trend toward the use of computer systems for noncomputational purposes. An increasing number of important, practical, and economically sound applications do not rely on the computer's ability to add, subtract, multiply, or divide. Rather, they rely on the computer's ability to receive and store information, to queue messages, to organize data, to search on keys, to establish communication links, and so on.

These kinds of activities form the basis for new growth in this industry in which the computer and its related equipment become the tools for the development of a whole range of services based on the presentation, storage, retrieval, transmission, and manipulation of information.

In this context, an information system consists of at least four distinguishable elements whose functions are:

- Computation and manipulation
- Information storage and retrieval
- Communications management
- Resource and task scheduling

These are just the functions so awkwardly encompassed by present-day monolithic operating systems.

In current systems, multiple functions are accomplished by the time-sequenced operation of a variety of programs designed to perform the various interlocking tasks. The computer itself is provided with an ingenious and extensive variety of order codes, register banks, mode switches, data channels, and interrupts in order to effectively perform the wide range of services required.

It is, however, possible that, with the increasing extension of computer systems into noncomputational services, the necessity—or even the desirability—of a single, general-purpose computing engine should be questioned.

With increasing demand for store-and-forward message systems, massive data banks, automated catalog services, transaction-oriented service networks, and the like, it may be economic to design specific functional entities to separately accomplish the tasks I've just mentioned.

I used the term "functional entity" deliberately to highlight the notion that the communication function, for example, would be designed with a communication processor specifically matched to communication software in order to be cost-effective for that task (similarly for a data structures management function).

The design of such a system (or system of systems) is, of course, a formidable task. The fact that many system problems cannot be "solved later with the software" mandates the early and precise definition of function, subfunction, and interface. (Or is this a blessing masquerading as a problem?)

In any event, the notion of such distributed-function operating systems is one that will probably gain some partisans in the next few years.

THE FUTURE

Where are we going then? What will computers be doing, six years hence, in 1976, thirty years after the birth of ENIAC?

Any seer who attempts to answer that question will find it humbling, I think, to recall what, in 1964, he thought 1970 would bring.

Nevertheless, the trends I've indicated seem massive enough to warrant some prognostication.

Transaction-processing will become a major consumer of computer goods and services. "Transaction-processing" refers to the time-shared use of computers, generally though extensive communication networks, to perform rote manipulations on a common data base. The most successful current exemplars are the various airline and ticket-reservation systems.

Transaction systems are like time-sharing in that they multiplex computer services among a wide audience. They are unlike time-sharing in two important ways. First, the object of the service is interaction among the terminals and via the data base. Time-sharing, in contrast, attempts to provide separation. ("You think you have your own private computer.") Second, transaction terminals are highly specialized and simplified. Time-sharing terminals, in contrast, are versatile and sufficiently generalized to enable them to serve a variety of functions not necessarily anticipated by the designer.

Future transaction systems will be placed in retail establishments—with point-of-sale data-entry terminals and on shop and factory floors—with parts-tag-driven inventory systems—both of these applications, again, employing highly specialized terminals.

The credit and banking industry will make extensive use of transaction-processing systems. The "checkless society" is probably coming—and transaction systems are what will make it work.

Examples of areas ripe for this kind of technology abound. Hospital information systems, involving the coordination of patient, doctor, nurse, pharmacist, accountant, and others, are under active development.

Computer-aided instructional systems—a topic of this conference—lie, I think, somewhere between what I have called time-sharing systems and what I have called transaction systems. I readily defer, however, to your more knowledgeable assessments on this matter.

The coming years will see the steady growth—and increasingly trusted use—of massive data bases. There will be a lot of effort put into how (in a conceptual sense) to effectively store, retrieve, index, and search for information. (This last is a substantial problem.) The cost of storing bits (in archival or tertiary stores) will drop substantially, facilitating the growth of such bases.

As our competence in transaction- and data-base-oriented systems grows, the business of business will become more computer-based. We find ways of tying together where are now separate systems: personnel, inventory, distribution, manufacturing, and accounting.

These techniques will find application in other areas in our complex society: communications, schools, courts.

Eventually, toward the end of the decade, I would expect to see the beginnings of an assault by the computer on what is presently man's most effective information-handling tool: paper. Putting marks on paper and saving the paper has been *the* information system since the Egyptian papyri.

Consider your own office: pad, pencil, typewriter, filing cabinet, books, journals, letters. We may talk about graphics terminals and data-transmission by telephone—but we don't work that way. My point is that I think we will.

By the 1980s, the office "system" will have been restructured—at least in a few places. The flow of ideas from head to fingers to typewriter keys to paper to mail and to storage, as presently modularized or factored, will be changed.

I have some ideas as to how it will be done. I'm sure you do too. However, I am less sure that I know how it will be done than I am that it will be done.

It's an exciting age!

THE DESIGN OF AN ECONOMICALLY VIABLE LARGE-SCALE COMPUTER-BASED EDUCATION SYSTEM*

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University of Illinois, Urbana, Illinois

The University of Illinois has been experimenting with a computer-based educational system (PLATO) for the past eight years. This system has evolved from a single terminal connected to the ILLIAC I (a medium-speed, 1954-vintage computer) to a computer classroom of 20 graphic-pictorial terminals connected to a Control Data Corporation 1604 computer. Some of the areas in which studies have been conducted are electrical engineering, geometry, biology, nursing, library science, pharmacology, chemistry, algebra, math drill, computer-programming, and foreign languages. This material has been presented by use of a variety of teaching strategies, ranging from drill and practice to student-directed inquiry. Based on these experiences and the data gathered over 70,000 student contact hours of credit teaching, this report describes the development of an economically viable teaching system. Some of our guidelines for developing the system's software and hardware are:

1. The computer should only be used when it is the best method of presentation. Less-expensive methods, such as programmed texts, films, slides, tape recorders, etc., should be used when appropriate.
2. The computer should be used as much as possible to simulate results in models constructed by the students rather than simply turning pages.
3. The system must be flexible and adaptable. It must be able to teach many

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subjects and present the lesson materials by a variety of teaching strategies. The system must change to meet the needs of the students and teachers, and not be limited to the off-the-shelf items presently available.

4. The method of integration into the educational system must be considered in the system design. For example, a school should be able to start with a single terminal for the incremental terminal cost instead of having to invest large sums of money for an entire system before the school has determined if it wants or needs computer-based education.

5. The cost of computer-based education should be comparable with the cost of teaching at the elementary grade school level. Cost-effectiveness should be determined by an hour-to-hour cost comparison (25 to 30 cents per terminal hour for use of the computer and terminal).

A present student terminal consists of a keyset and a television monitor as shown in Fig. 1. Information viewed on the television monitor is composed of a slide selected by the computer (random-access time less than 1 millionth of a second) and a superimposed image of graphs, diagrams, and/or alphanumeric characters drawn by the computer in a point-by-point fashion. The student uses the keyset for constructing answers and questions and for setting up simulated or real experiments as well as for controlling his progress through the lesson material. The computer responds to the student's requests within one-tenth of a second.

The computer also controls other devices, such as movie projectors, lights, etc. The students at the terminals can interact with each other through the computer, thus permitting games to be played which require communication between the players.

In addition to keeping detailed records of the student's performance, the computer can provide individualized instruction, immediate feedback, and remedial training by the use of complex internal branching and the alteration of presentation or type of material based on the student's past performance. These unique features seem to make the computer an ideal instructional device for developing cognitive skills.

To encourage development of critical thinking skills, the author sets up the teaching strategy and presents the student with questions or problems so the student must think about what information he needs, about possible solutions to the problems or sources of information, interpret the data gathered, and test his solution. The computer immediately provides appropriate feedback to open-ended questions, thus reinforcing a correct approach, or in the case of an incorrect response, encouraging the student to a new approach.

The computational use of the computer appears in several ways. First, experiments can be simulated by the computer, immediately providing the student with results he uniquely requested. These same results might require hours or even days to calculate by hand. Second, a large amount of computation is involved in processing student responses. The more flexibility provided for the student to answer a question, the more feedback is needed to inform him of the correctness of his response. When only multiple-choice responses are required, the processing is relatively simple, but when the student is permitted to construct long alphanumeric and graphic responses the computer must analyze his answer to see if it is equivalent to a correct response, check for spelling and completeness of the answer, as well as inform him which part of an incorrect answer is unacceptable.

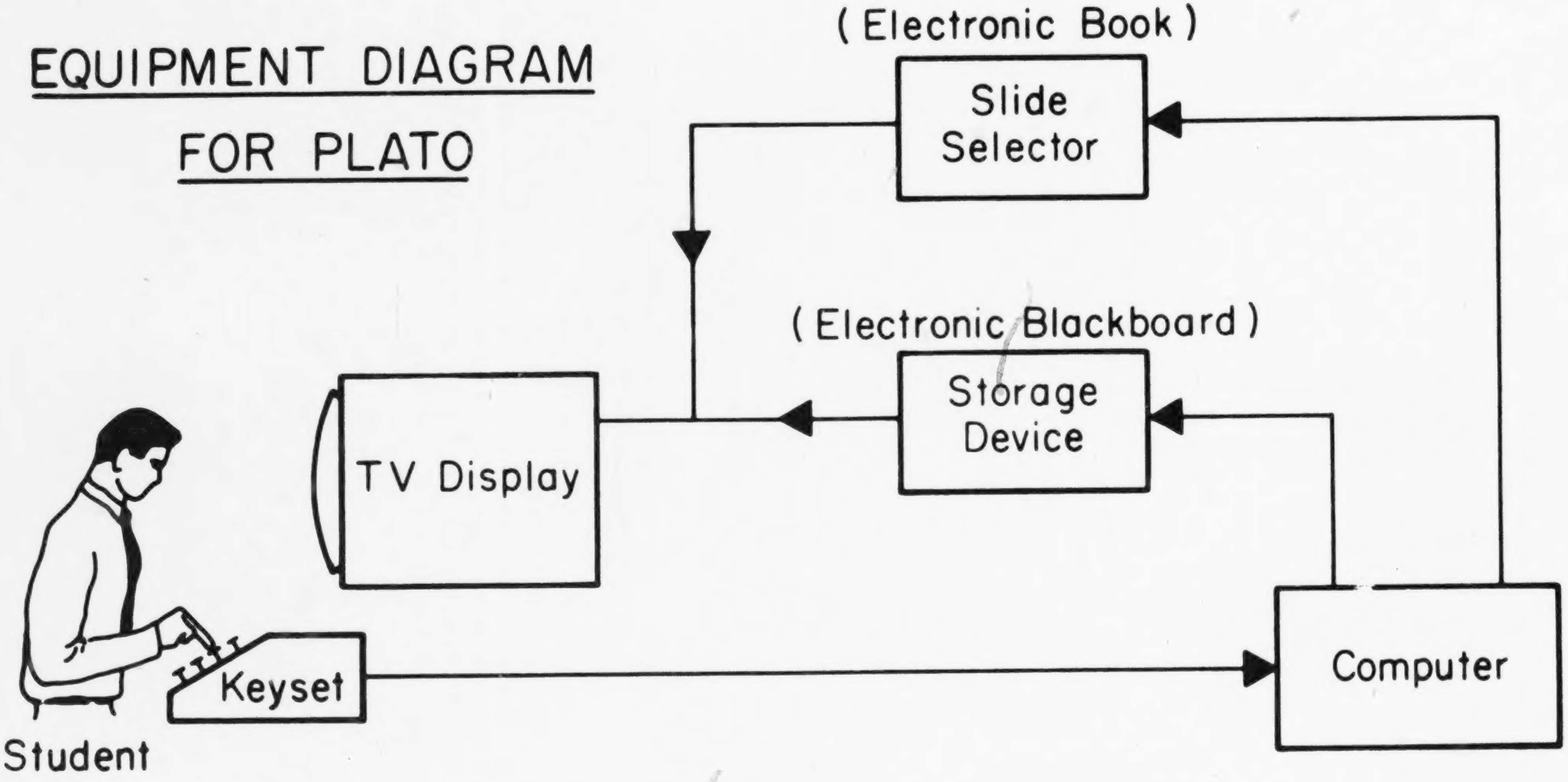
EQUIPMENT DIAGRAM
FOR PLATO
(Electronic Book)
Slide Selector
(Electronic Blackboard)
Storage Device
TV Display
Computer
Keyset
Student

Fig. 1—Student terminal

Whenever possible, algorithms are used to determine the correctness of the student's response. For example, when the student is asked to give a positive even integer, the student's answer is checked to see if it is positive and then it is divided by two and checked for a remainder. If there is no remainder, the answer is correct. The use of algorithms instead of comparing the answer against a long list of pre-stored answers not only makes the system more flexible but also saves memory space. In some cases this approach is almost a necessity. For instance, in teaching algebraic proofs, students can prove theorems in any manner as long as their statements follow logically from the available axioms and their previous statements. We have one example in which the author of the material was unable to prove a theorem in the twelve lines provided and, thus, was unable to supply even one pre-stored solution. Nonetheless, one student was able to complete the proof in the required twelve lines and was told by the computer he was correct.

To illustrate further how the computer interacts with the student we will describe some sequences taken from lessons in geometry, electrical engineering, and maternity nursing.

A user's computer language consisting of English directives was used to write a series of 15 lessons in informal geometry.* These lessons were to give 7th and 8th grade students an understanding of geometric concepts. A grid is provided on which the student draws and manipulates geometric figures. The computer is used to determine the correctness of the figure, independent of its size, location, and orientation on the grid. The student must select points of the grid to be used as the vertices of his figure. To do this, eight keys on his keyset have been defined which move a bright spot around on the grid. (Figure 2 shows a diagram of these keys. The arrows on the keycaps indicate the direction in which the key moves the bright spot on the grid.) Once a student has decided on a point, he communicates his selection to the computer by pressing the "MARK" key. He presses the "CLOSE" key to close the

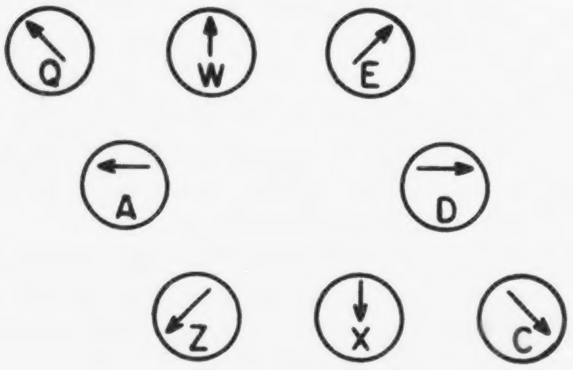

Fig. 2—Keys on student terminal

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* This project was supported by the U.S. Office of Education under Contract OE-6-10-184, and by the National Science Foundation under NSF G-23554.

figure (connect the first point to the last point). To judge the figure the student presses "NEXT" and the computer either okays the figure or indicates the student's error.

In the following sequence, the student is asked to draw quadrilaterals with a single line of symmetry. In Fig. 3a the student is instructed to draw a quadrilateral with one line of symmetry: the two possibilities are an isosceles trapezoid and a kite. He selects the points he wishes to use for his figure and marks them. Figure 3b shows the partial construction of the trapezoid. When four points have been marked the student closes his figure and asks the computer to judge it. In Fig. 3c the completed figure is judged and the computer points out to the student that the symmetry line for an isosceles trapezoid does not go through the verices.

The student then moves to the next page of the lesson and is asked to draw a quadrilateral with a single line of symmetry that does go through the vertices (Fig. 3d). The student, however, reconstructs the trapezoid. The computer, when judging the figure, recognizes the duplication and tells the student that he has drawn the same figure as he drew before (Fig. 3e). The student then draws a kite which has a single line of symmetry through vertices and the figure is judged "OK" (Fig. 3f).

For our second case we use a sequence taken from a circuit analysis course in electrical engineering (Fig. 4). The student has just analyzed a circuit containing a battery, a switch, an inductor, and a resistor, all connected in series. His task is to determine the value of the inductor and resistor that causes the current waveform to pass through the points marked on the graph after the switch is closed. He is instructed to make the resistor value small and notice the effect on the final value of the current. By manipulating these values, the student gains an intuitive feeling for the effects of the inductance and resistance, and he can proceed in an orderly way to determine their correct values.

The third example is taken from a maternity nursing lesson* where the student is presented with a question which asks her to list two cardiovascular compensations which occur as a result of the increased blood volume during pregnancy (Fig. 5).

The student, needing information to answer this question, presses the button on her keyset labeled "INVEST." She is then presented with a slide where she indicates that she wishes to investigate "Anatomic and Physiological Changes of Pregnancy."

After choosing her area of investigation, she is presented with a slide which requests further specification. Here the student indicates that she wishes information concerning changes which occur in the circulatory system during the third trimester of pregnancy. Having done this, she presses the "ANSWER" button and the computer-generated information tells her there is an "increase in blood volume, a 50-percent increase in cardiac work load, left ventricular hypertrophy, and vasodilation produced by an increase in progesterone." Deciding that increased work load is one compensation, she considers left ventricular hypertrophy but needs to further clarify the word hypertrophy. By pressing the button labeled "DICTIONARY," she is presented with a list of terms used in the lesson. The student types the word "hypertrophy" and the computer supplies the definition "increase in size of an organ or structure."

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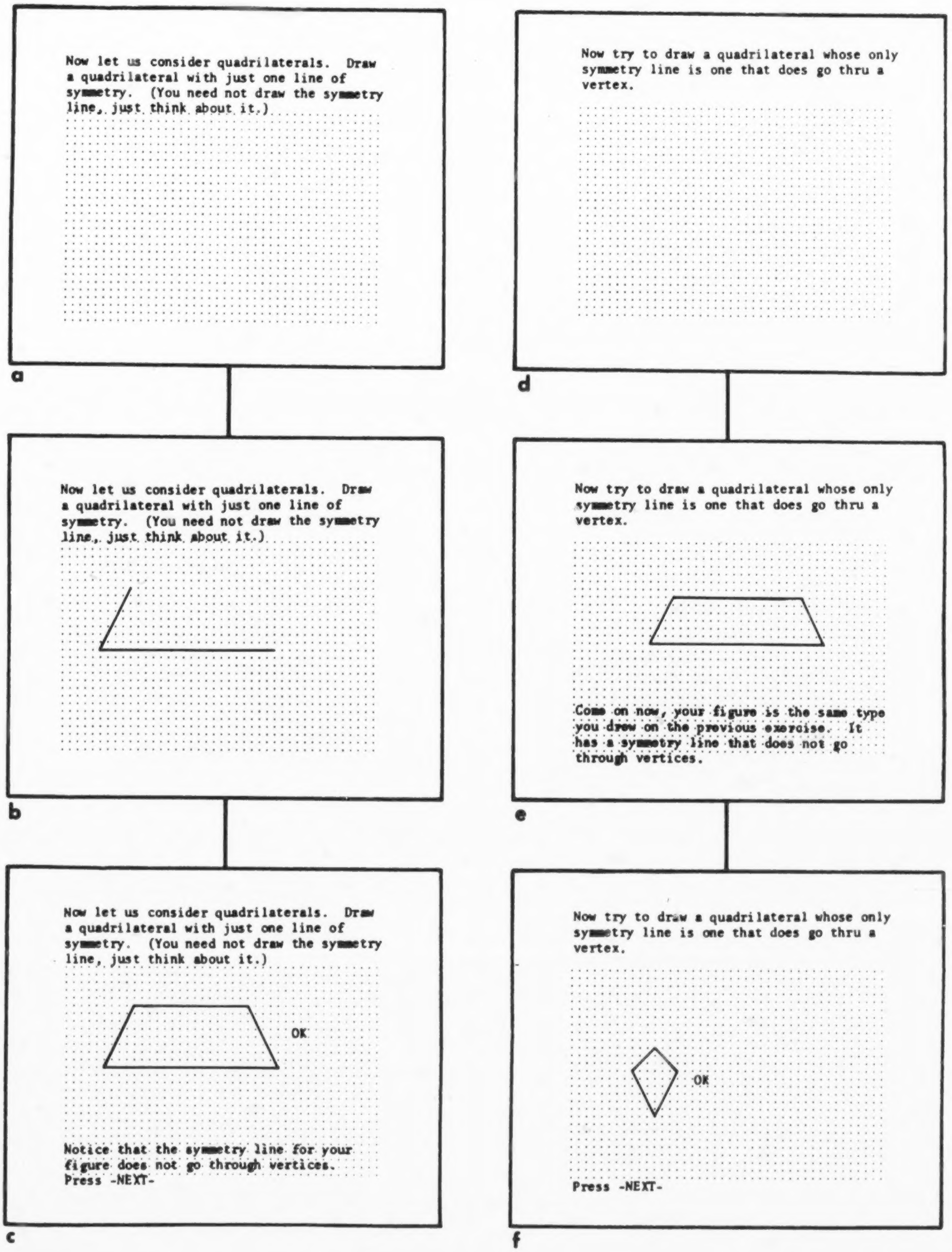
* This project is supported by PHS Training Grant No. NPG 188, Division of Nursing, PHS, U.S. Department of Health, Education and Welfare.



Now let us consider quadrilaterals. Draw a quadrilateral with just one line of symmetry. (You need not draw the symmetry line, just think about it.)

Now let us consider quadrilaterals. Draw a quadrilateral with just one line of symmetry. (You need not draw the symmetry line, just think about it.)

Now let us consider quadrilaterals. Draw a quadrilateral with just one line of symmetry. (You need not draw the symmetry line, just think about it.)

Notice that the symmetry line for your figure does not go through vertices.
Press -NEXT-

Now try to draw a quadrilateral whose only symmetry line is one that does go thru a vertex.

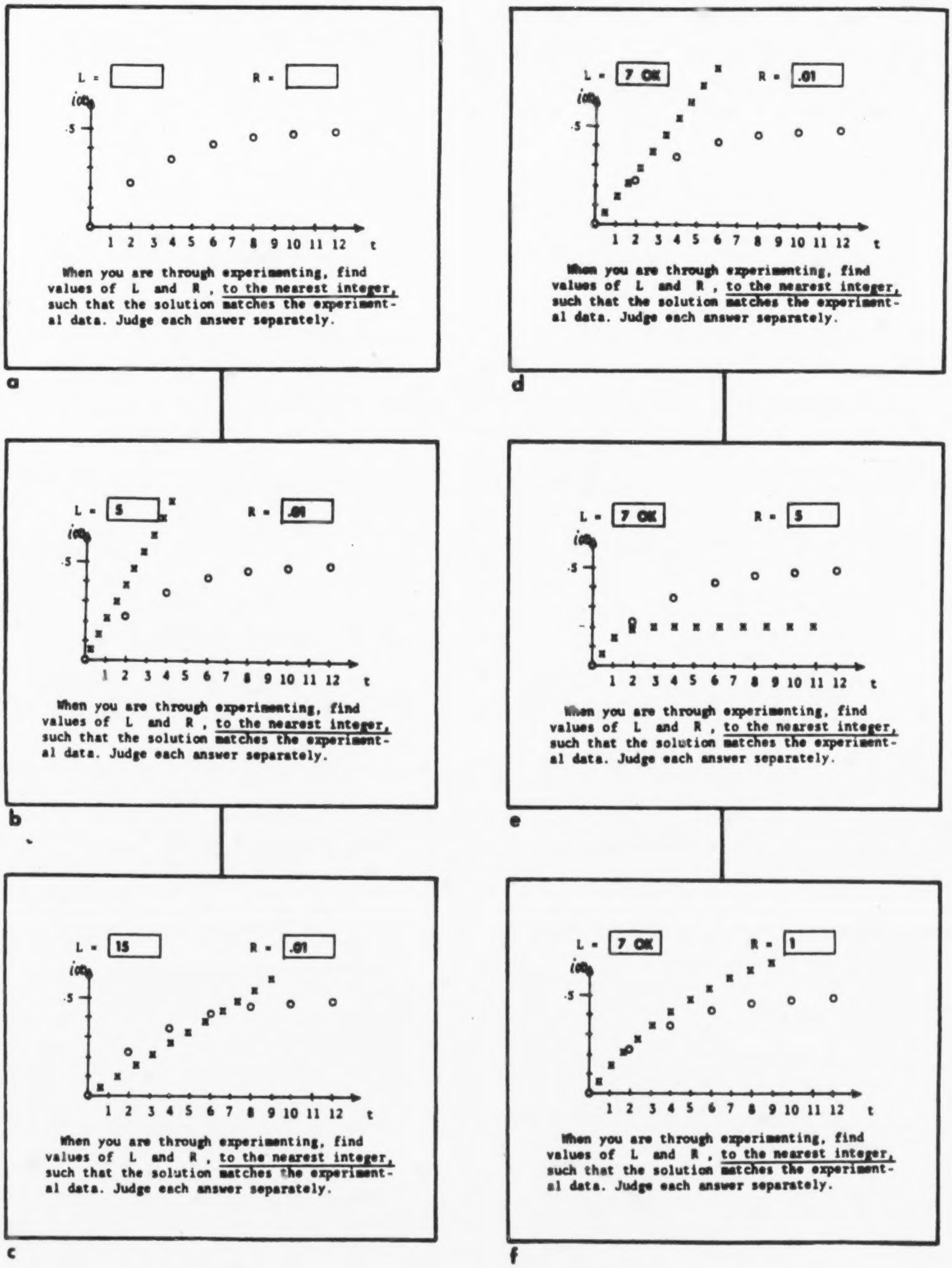
Now try to draw a quadrilateral whose only symmetry line is one that does go thru a vertex.

Come on now, your figure is the same type you drew on the previous exercise. It has a symmetry line that does not go through vertices.

Now try to draw a quadrilateral whose only symmetry line is one that does go thru a vertex.

Press -NEXT-

Fig. 3—An example from a geometry lesson



a
L =
R =
i(t)
.5
1 2 3 4 5 6 7 8 9 10 11 12 t

When you are through experimenting, find values of L and R , to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

b
L = 5
R = .01
i(t)
.5
1 2 3 4 5 6 7 8 9 10 11 12 t

When you are through experimenting, find values of L and R , to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

c
L = 15
R = .01
i(t)
.5
1 2 3 4 5 6 7 8 9 10 11 12 t

When you are through experimenting, find values of L and R , to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

d
L = 7 OK
R = .01
i(t)
.5
1 2 3 4 5 6 7 8 9 10 11 12 t

When you are through experimenting, find values of L and R , to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

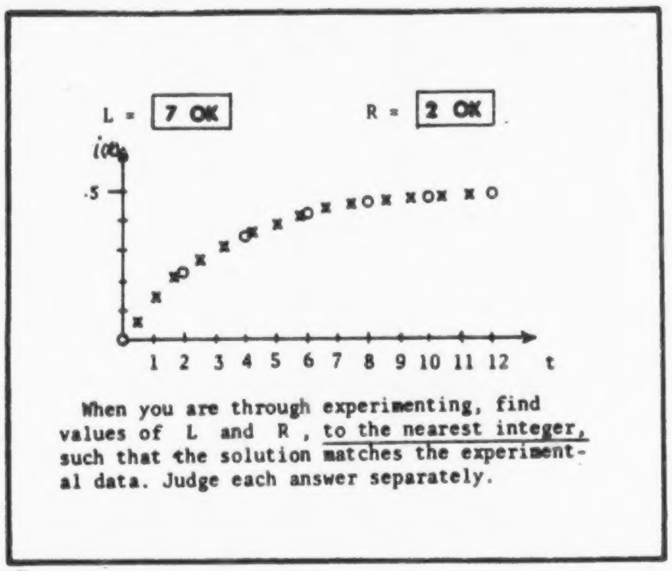
e
L = 7 OK
R = 5
i(t)
.5
1 2 3 4 5 6 7 8 9 10 11 12 t

When you are through experimenting, find values of L and R , to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

f
L = 7 OK
R = 1
i(t)
.5
1 2 3 4 5 6 7 8 9 10 11 12 t

When you are through experimenting, find values of L and R , to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

Fig. 4—An example from a circuit-analysis lesson



L = 7 OK R = 2 OK

When you are through experimenting, find values of L and R , to the nearest integer, such that the solution matches the experimental data. Judge each answer separately.

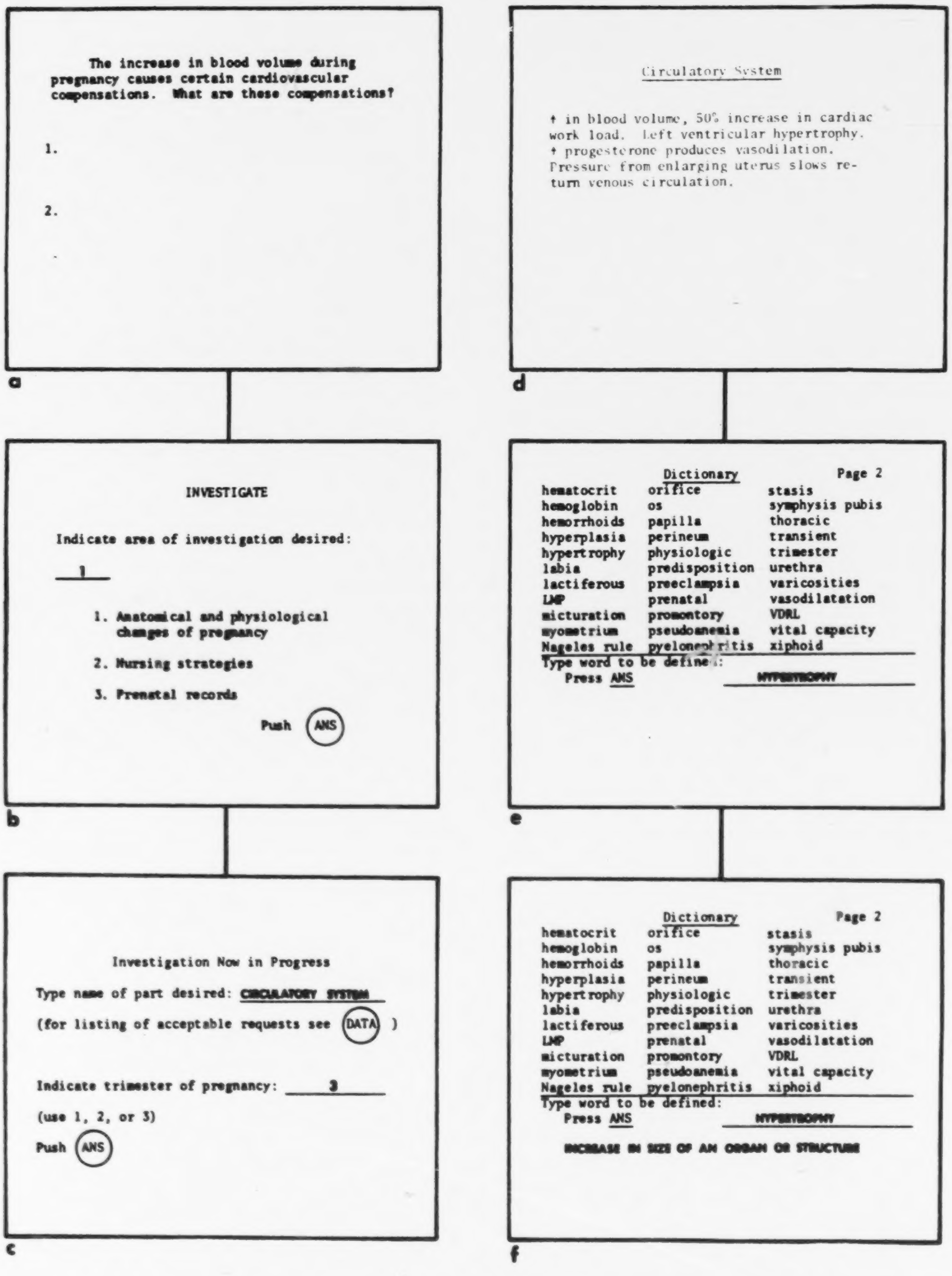
9

Fig. 4—continued

By pressing the button labeled "AHA," the student is returned to the question on which she was working. Here she types the answer "hypertrophy of the left ventricle" and the computer judges it "OK." However, the answer "the left ventricle" is judged "NC," that is, correct but not complete. Rewording the correct answer, the student types "the left ventricle enlarges" and the computer responds "OK." However, when the student presses the "CONTINUE" button to advance to the next page, the computer prints out "DUPLICATE ANSWER." Next, the response "the left ventricle decreases in size" is entered. The computer responds "NO" and X's out the word "decreases." Before the student can continue, she must change one of her responses to a correct answer which differs from the first.

Records of each student's request (his identity, the key pushed, and the time to the nearest sixtieth of a second) are stored on magnetic tape. These data are processed by the same computer that is used for teaching. We have used these records for improving course content, designing better teaching strategies, as well as for planning new, economically viable computer-based education systems.

On the basis of CERL's experience with early PLATO systems, certain design philosophies for the proposed system have been formulated. First, each student terminal requires a keyset and a display, both connected to an inexpensive data-transmission system which can also drive optional equipment such as random-access audio devices, reward mechanisms, movie films, lights, and so forth. Second, each student terminal must be capable of superimposing randomly accessed color-slide images on the computer-generated graphics. Third, the system should be controlled by a large-scale centrally located computer rather than by many small computers located at the classroom sites. This decision is based upon social and administrative factors as well as on system economics. Semiconductor large-scale integration techniques may some day make the use of small computers as effective as large ones, but



The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.

2.

INVESTIGATE

Indicate area of investigation desired:

1

1. Anatomical and physiological changes of pregnancy
2. Nursing strategies
3. Prenatal records

Push (ANS)

Investigation Now in Progress

Type name of part desired: CIRCULATORY SYSTEM

(for listing of acceptable requests see (DATA))

Indicate trimester of pregnancy: 3

(use 1, 2, or 3)

Push (ANS)

Circulatory System

↑ in blood volume, 50% increase in cardiac work load. Left ventricular hypertrophy.
↑ progesterone produces vasodilation.
Pressure from enlarging uterus slows return venous circulation.

```
                 Dictionary                 Page 2
hematocrit     orifice          stasis
hemoglobin     os               symphysis pubis
hemorrhoids    papilla          thoracic
hyperplasia    perineum         transient
hypertrophy    physiologic      trimester
labia          predisposition   urethra
lactiferous    preeclampsia     varicosities
LMP            prenatal         vasodilatation
micturation    promontory       VDRL
myometrium     pseudoanemia     vital capacity
Nageles rule   pyelonephritis   xiphoid
Type word to be defined:
   Press ANS                    HYPERTROPHY
```

```
                 Dictionary                 Page 2
hematocrit     orifice          stasis
hemoglobin     os               symphysis pubis
hemorrhoids    papilla          thoracic
hyperplasia    perineum         transient
hypertrophy    physiologic      trimester
labia          predisposition   urethra
lactiferous    preeclampsia     varicosities
LMP            prenatal         vasodilatation
micturation    promontory       VDRL
myometrium     pseudoanemia     vital capacity
Nageles rule   pyelonephritis   xiphoid
Type word to be defined:
   Press ANS                    HYPERTROPHY

     INCREASE IN SIZE OF AN ORGAN OR STRUCTURE
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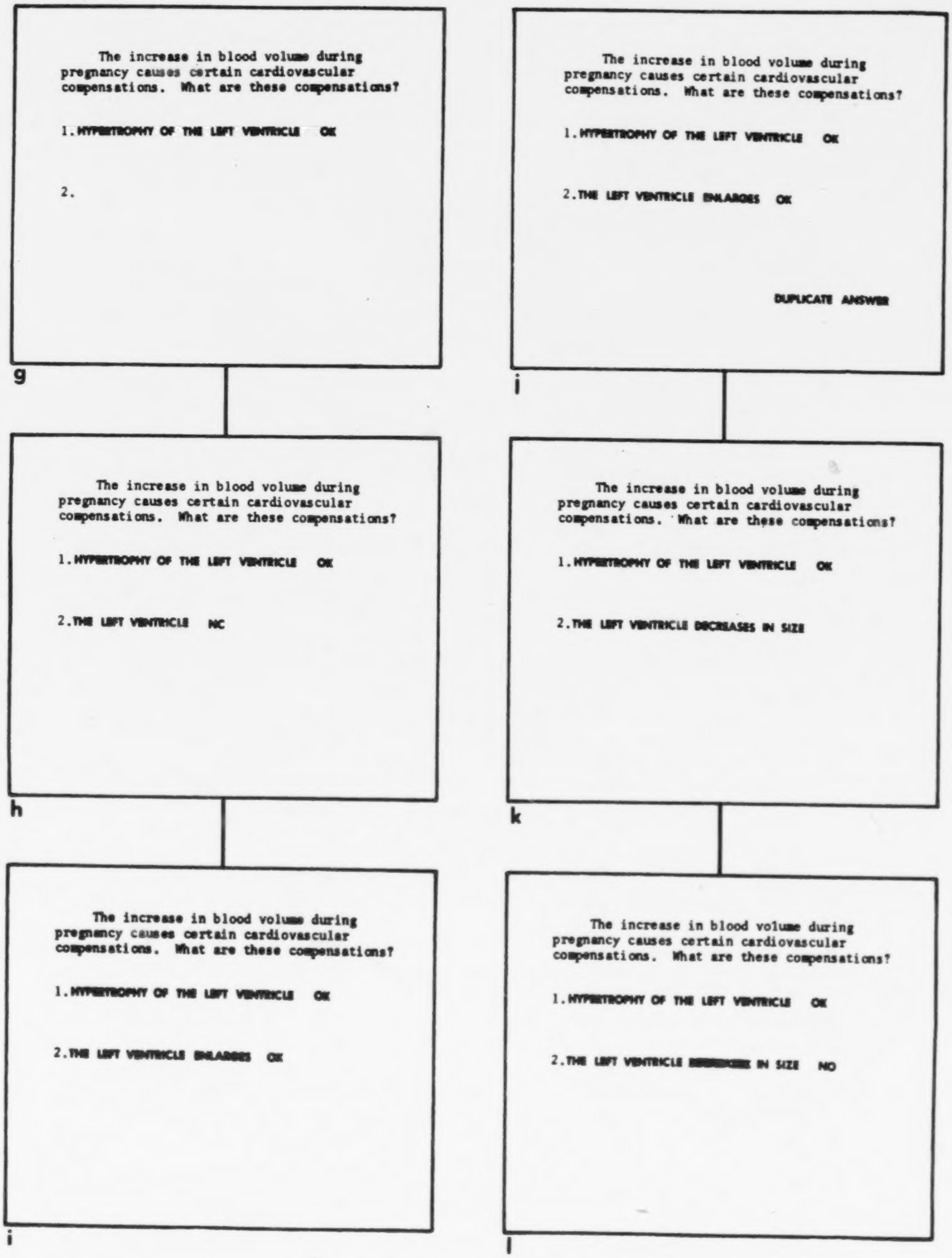
Fig. 5—An example from a maternity nursing lesson



The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE NC

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE ENLARGES OK

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE ENLARGES OK

DUPLICATE ANSWER

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE DECREASES IN SIZE

The increase in blood volume during pregnancy causes certain cardiovascular compensations. What are these compensations?

1.HYPERTROPHY OF THE LEFT VENTRICLE OK

2.THE LEFT VENTRICLE [illegible] IN SIZE NO

Fig. 5—continued

the added human expense of operating a computer center does not promise to scale as effectively. It is our opinion that the initial low cost of a single terminal will permit tightly budgeted public school systems to economically incorporate computer-based teaching into their programs. The number of terminals could be increased or decreased as the needs of the school system dictate. Fourth, the cost per student contact hour for the proposed system must be comparable with equivalent costs of traditional teaching methods.

Before discussing an economical system design from the technical viewpoint, it is necessary to consider the cost of producing lesson material. Reported costs have ranged over a factor of 10 for producing similar lesson material. The differences in author languages can account for this wide range. The author language must be just as natural for the teacher to use as the teaching strategy is for the student to use. However, in the long run, the cost of lesson material should constitute only a small fraction of the educational costs just as the textbooks and lesson materials represent only a small part of educational costs today.

Preparing a good CAI course is roughly equivalent in effort to writing a good textbook. Most good authors are quite willing to produce textbooks at a 10 to 15 percent royalty rate which yields to them approximately 80 cents per student. Most textbooks are used in courses which have at least 40 hours of classroom instruction. The cost of royalties, reproduction, and distribution of lesson material total to $1.20 per student, and when used for 40 hours of instruction yields an eventual cost of approximately 3 cents per student hour of instruction. The reproduction and distribution of materials for computer-assisted instruction terminals promises to be very inexpensive (approximately 40 cents per student for visual and audio materials).

Statistical records of over 70 million requests on PLATO indicate that the average request rate per student depends upon the teaching strategy used, but the product of the average request rate and the average processing time is relatively constant. For example, when using a drill-type teaching strategy the average request rate per student is one request every 2 seconds and the average processing time is 10 milliseconds. When using a tutorial or inquiry strategy, the average request rate per student is one request every 4 seconds, but the processing time is 20 milliseconds. We will base our calculations on the 20-millisecond processing time which is equivalent to executing approximately 1,000 instructions in the CDC 1604.

The request rate probability density function versus computer execution time is approximately an exponential curve; therefore, student requests requiring the least amount of computer time occur most frequently. For example, the simple and rapidly processed task of storing a student's keypush in the computer and writing the character on his screen represents 70 percent of the requests. On the other hand, the lengthy process of judging a student's completed answer for correctness, completeness, spelling, etc., occurs only 7 percent of the time.

Several existing large-scale computers can perform about 4×10^6 instructions per second. Even if we double the number of instructions needed, providing 2,000 per student request, it is seen that these large-scale computers require an average processing time of only 500 microseconds per request. Allowing a safety factor of two to insure excellent system response time, the system can accept an average of 1,000 requests per second. This safety factor implies that the computer will be idle approximately 50 percent of the time. However, the computer time not utilized in processing the student requests can be effectively used for other purposes such as background batch-processing. Since the average student request rate is 1/4 of a request per second, the system can handle up to 4,000 students simultaneously, allowing one millisecond to process a request.

Assume that the student input arrival time is Poisson distributed (a reasonable assumption for 4,000 independent student stations), and that the request-rate probability density function versus computer execution time is approximately exponential (PLATO statistical records substantiate this).

From queueing theory [2, 7] the expected waiting time E(w) that elapses before the computer (single channel) will accept a given student's request is given by

$$E(w) = \frac{\rho^2 + m\sigma_t^2}{2m(1 - \rho)} \tag{1}$$

where

m = request rate = 1.000 request/sec
σ_t = execution time standard deviation = 500×10^{-6} sec
$E(t)$ = execution time expected value = 500×10^{-6} sec
ρ = $mE(T) = 0.5$

These values yield an expected waiting time E(w) of 500 microseconds. The probability P(w) that a student's request will wait a time, w, or longer before being served by the computer is given by

$$P(w) = \rho \exp \frac{-w(1 - \rho)}{E(T)} \tag{2}$$

The probability that a student must wait for 0.1 second or longer is negligible. Hence the probability of a student's request queue becoming long, or of the student's experiencing a noticeable delay is very small.

Presently, each student needs to be assigned approximately 300 words of extended core memory to be treated individually. The maximum used in any teaching strategy has been 600 words per student. Let us allow on the average 500 words (50 bits) for each student for a total of 2×10^6 words for 4,000 student terminals. Our data show that 20 percent of the computer instructions refer to these words of unique student storage. Therefore, the system must be capable of rapidly transferring data between the slower extended core storage and the high-speed core memory. Some existing computers are capable of transferring data at 10^7 words per second, requiring only 50 microseconds to transfer the data each way between the memory units. This transfer time is acceptable.

The peak data rate from the computer to each student station is limited to 1,200 bits per second to permit data transmission over low-grade telephone circuits, a system feature made possible by the use of the plasma display panel discussed later. For 4,000 stations the worst-case data rate would be about 4.8 million bits per second, well within the present state of the art for buffering data out of a computer.

Summarizing the computer requirements, therefore, the central computer requires about 2 million words of extended core memory capable of high-speed transfer rates to the main computer memory, it must have an execution time of approximately 4 instructions per microsecond and be capable of transmitting data at a rate of 4.8 million bits per second. There should be a sufficiently large memory (64k to 128k words) in the central processing unit for storing lessons (1k to 2k words per lesson) and for the various teaching strategies. Several existing computers meet these requirements.

The economic feasibility of the proposed teaching system is dependent upon the newly invented plasma display panel (or equivalent device) now under development at the University of Illinois and other laboratories. This device combines the properties of memory, display, and high brightness in a simple structure of potentially inexpensive fabrication. In contrast to the commonly used cathode-ray-tube display, on which images must be continually regenerated, the plasma display retains its own images and responds directly to the digital signals from the computer. This feature will reduce considerably the cost of communication distribution lines. The plasma display is discussed in detail in the listed references. Briefly, it consists of a thin glass panel structure containing a rectangular array of small gas cells (about 0.015 inch density of about 40 cells per inch—see Fig. 6). Any cell can be selectively ignited (gas discharge turned on or turned off by proper application of voltages to the orthogonal grid structures without influencing the state of the remaining cells). Figure 7 shows a small, developmental panel displaying two characters. Each of these characters is only 1/8 inch in height. The plasma panel is transparent, allowing the superimposition of optically projected images.

A schematic of a proposed student terminal using the plasma display is shown in Fig. 8. The display will be approximately 12 inches square and will contain 512 digitally addressable positions along each axis. A slide selector and projector will allow prestored (static) information to be projected on the rear of the glass panel display. This permits the stored information to be superimposed on the panel which contains the computer-generated (dynamic) information. A prototype random-access slide selector for individual use is shown in Fig. 9. This projector is digitally addressable, pneumatically driven, and contains a matrix of 256 images on an easily removable 4-inch-square plate of film. The film plate is mounted on a Cartesian-coordinate slide mechanism and can be simultaneously translated along either of the two coordinate axes to bring a desired image over a projector lens. The positions along each coordinate axis are selected by a set of four pneumatic cylinders mounted in series. The stroke length of each cylinder is weighted 8,4,2,1, the length of the smallest being 1/4 inch. Each slide selection requires less than three cubic inches of air at 8 psi. Based upon the prototype model now being tested, a low-cost image selector with approximately 0.2 second random-access time is anticipated.

Data arriving from the computer via a telephone line enter the terminal through an input register. As previously stated, data rates to the terminal will be held to 1,200 bits per second. Assuming a word length of 20 bits, the terminal could receive data at 60 words per second, an important design feature when considering standard TV tariff for communicating. With proper data formats, data rates will be adequate for the applications envisaged. For example, packing three character codes per word will permit a writing rate of 180 characters per second, which is a much faster rate than that of a good reader. Using 18 bits to specify a random point on the 512×512 array, 60 random points per second can be plotted. If the x increment is assumed such as when drawing graphs, 120 graph points per second can be plotted.

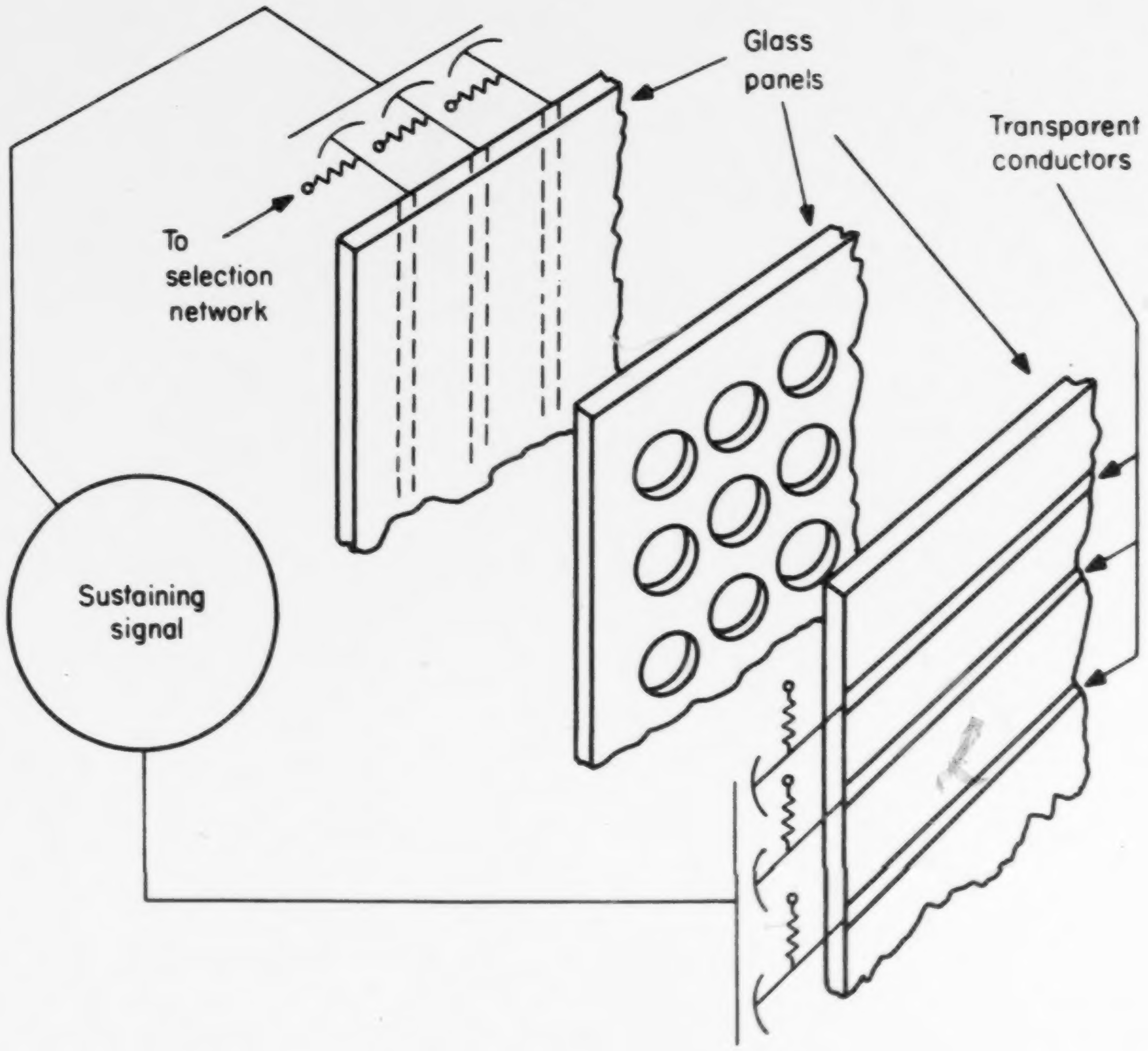


Fig. 6—Plasma display

In addition, continuous curves requiring only 3 bits to specify the next point can be drawn at rates of 360 points per second. The keyset will provide the student with a means of communicating with the computer. The problem of converting the fast parallel output data from the computer into serial data for transmission to terminals at 1,200 bits per second has been studied. This can be solved by the use of small-size buffer computers performing the parallel-to-serial data conversion.

In the situation where a large number of students are located at considerable distances from the central computer, costs can be lowered drastically by use of a coaxial line instead of numerous phone lines. For example, the cost of a 4.5 MHz TV channel is approximately $35 per month per mile, whereas the rate for a 3kc telephone line is approximately $3.50 per month per mile. Each TV channel can handle at least 1,500 terminals on a time-shared basis, each terminal receiving 1,200

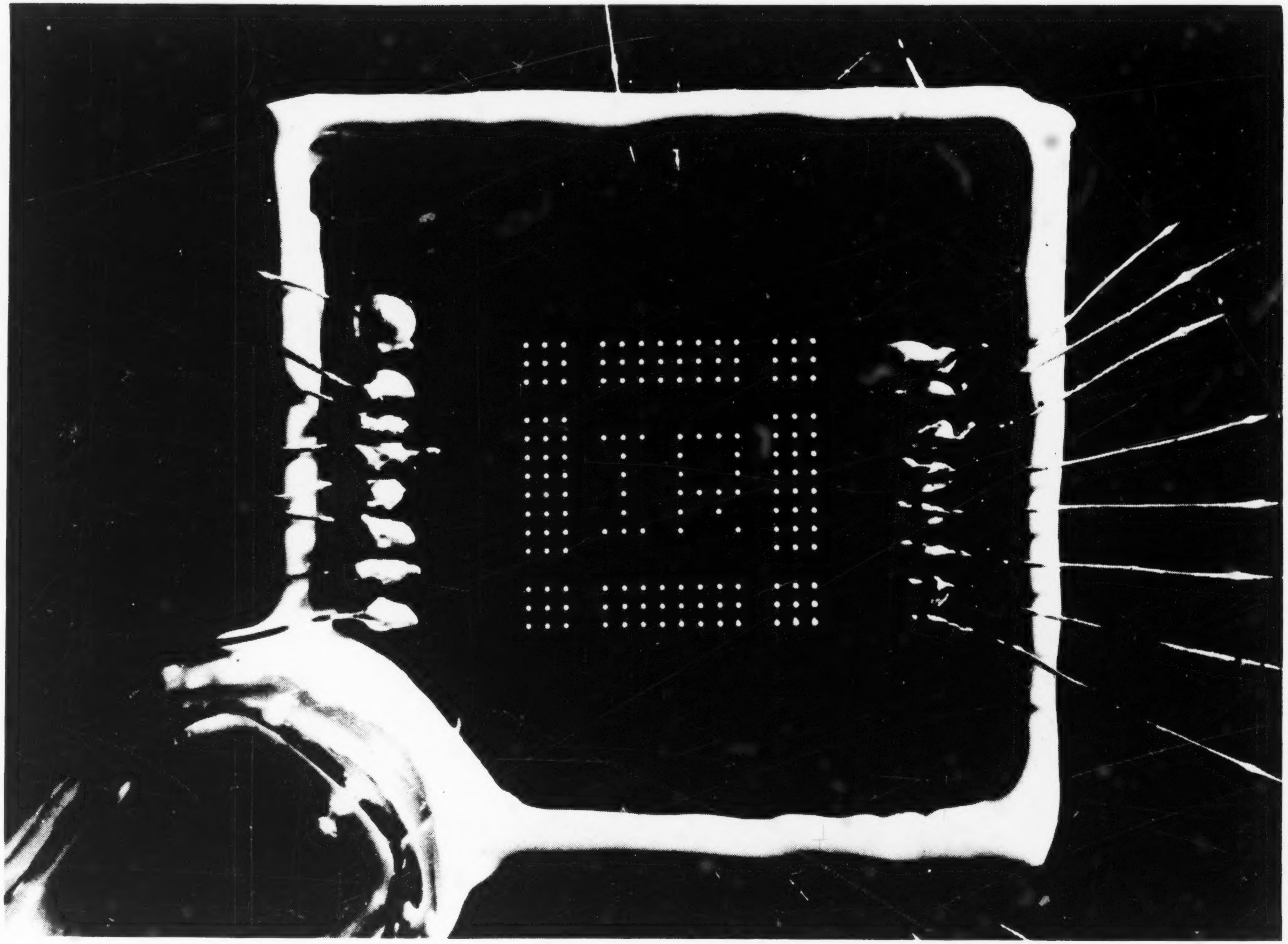
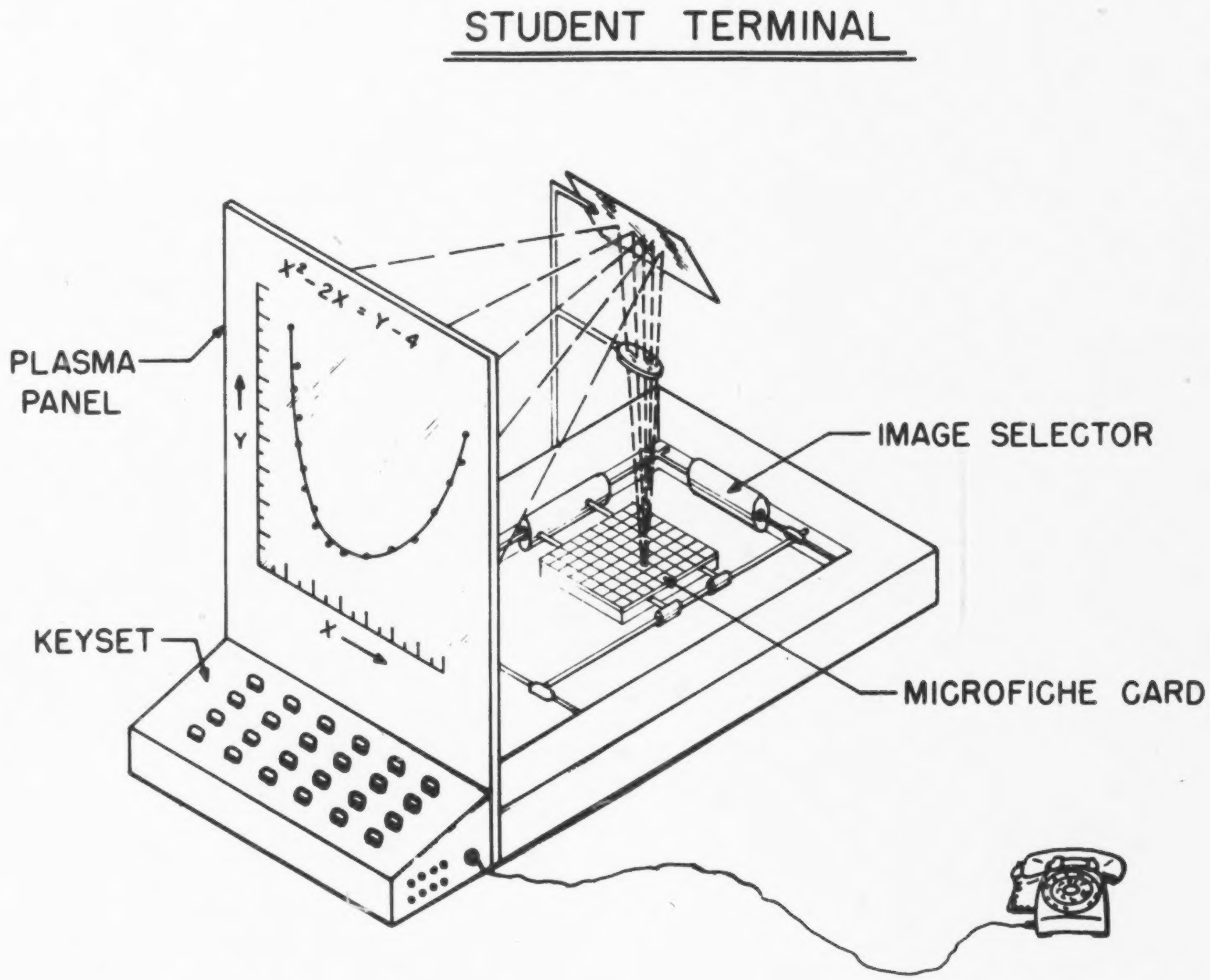


Fig. 7—Developmental panel


STUDENT TERMINAL

PLASMA PANEL
KEYSET
IMAGE SELECTOR
MICROFICHE CARD
$X^2-2X=Y-4$
Y
X

Fig. 8—Proposed student terminal

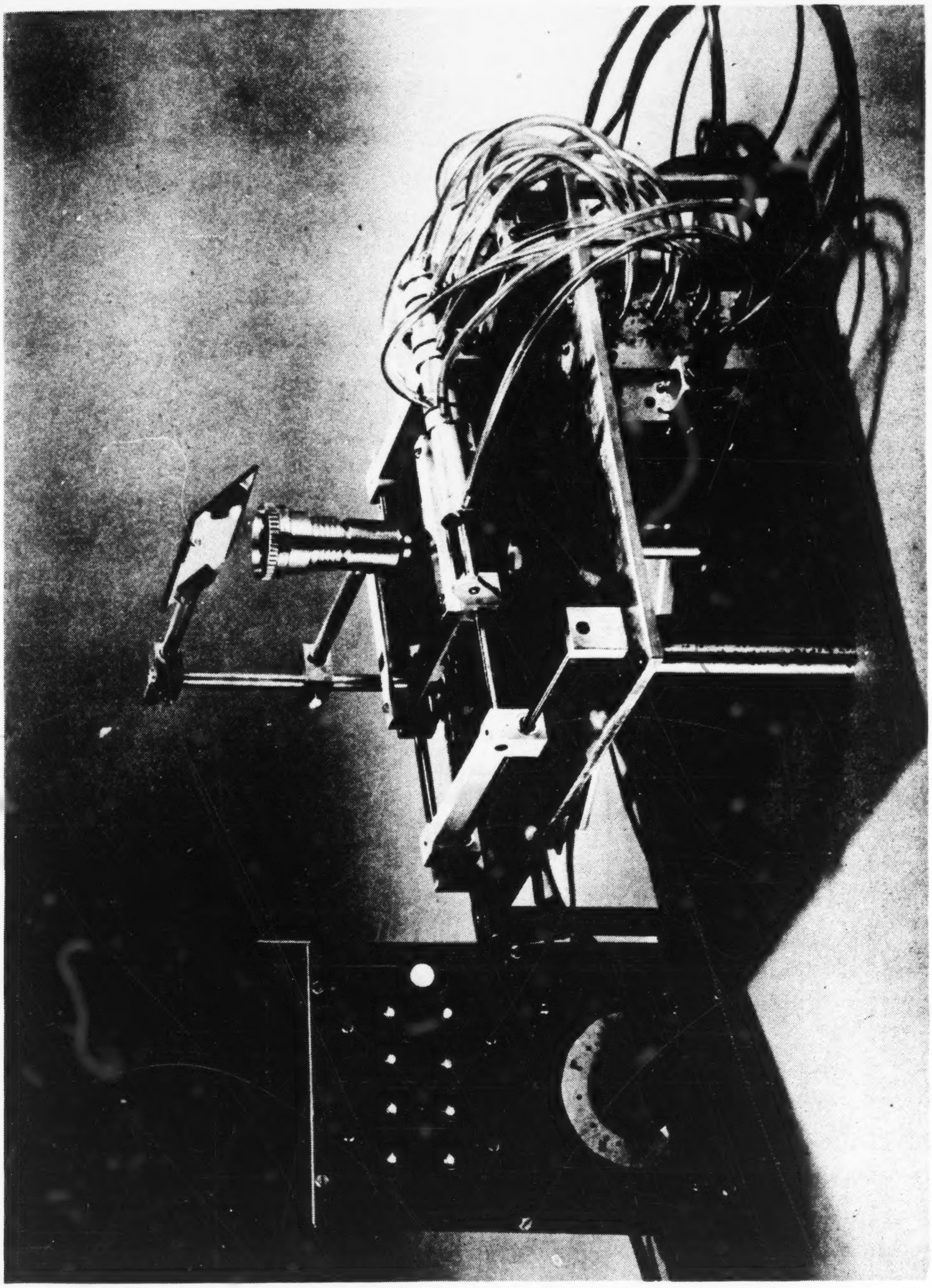


Fig. 9—Prototype random-access slide selector

bits per second. Hence, for an increase in line cost of a factor of 10 over that of a single channel, an increase of a factor of 1,500 in channel capacity can be obtained. In addition to a coaxial line transmitting 1,500 channels at 1,200 bits per second from the computer to the terminals, a data line for transmitting the student keyset information back to the main computer center is required. A data channel of 100,000 bits per second capacity, available from Bell Telephone, can handle 1,500 students, allowing 60 bits per second to each student. The cost for this line is approximately $15 per month per mile. Data to remote locations will be transmitted by a coaxial line to a central point; from this point local telephone lines rented on a subscriber's-service basis would transmit the proper channel to each student terminal. A block diagram of a proposed distribution system to several remote points is shown in Fig. 10.

Over 200 cities, and on a more limited scale many schools, already use community-antenna television systems or closed-circuit TV. Because FM radio had already established itself prior to the spread of television, a frequency gap existed between channels 5 and 6 which is almost 8 channels wide. These existing channels can be used to communicate to over 12,000 home terminals.

The mainframe cost of a computer meeting the specified requirements is approximately 2.5 million dollars. The additional cost for 2 million words of memory and other input-output equipment is approximately 2 million dollars. An estimate for the system software, including some course development programming, is another 1.5 million dollars. The total of 6 million dollars amortized over the generally accepted period of 5 years yields 1.2 million dollars per year.

Assuming that the 4,000-terminal system will be in use 8 hours a day for 300 days a year, there are approximately 10 million student contact hours per year. The system cost, excluding the terminals, is thus 12 cents per student contact hour. In order for the equipment cost to be comparable to a conventional elementary school classroom cost of approximately 27 cents per student contact hour, the terminal costs must be limited to 15 cents per student contact hour, or to a total cost of about 7.5 million dollars over a 5-year period. The cost for each of the 4,000 terminals, which included a digitally addressed graphical display device and its driver, a keyset, and a slide selector, must therefore be a maximum of approximately $1,900. Present indications are that this cost can be met.

Data distribution costs for a CBE center approximately 100 miles from the main computer are approximated as follows. The coaxial line rental is approximately $3,500 per month, or $2.35 per terminal per month, based on 1,500 terminals. The 100,000 bit per second wide-band data channel line is approximately $1,500 per month, or $1.00 per terminal per month. Allowing $3.00 per terminal per month for a private telephone line from the coaxial terminals to each student terminal gives a total data distribution cost of $6.35 per terminal per month, or 4 cents per student contact hour if each terminal is used 160 hours per month. The author costs were discussed previously.

These costs, based on the above assumptions, are summarized in Table 1. The earning power of the computer for the remaining 16 hours each day and for the idle time between student requests, which would further reduce costs, has not been included.

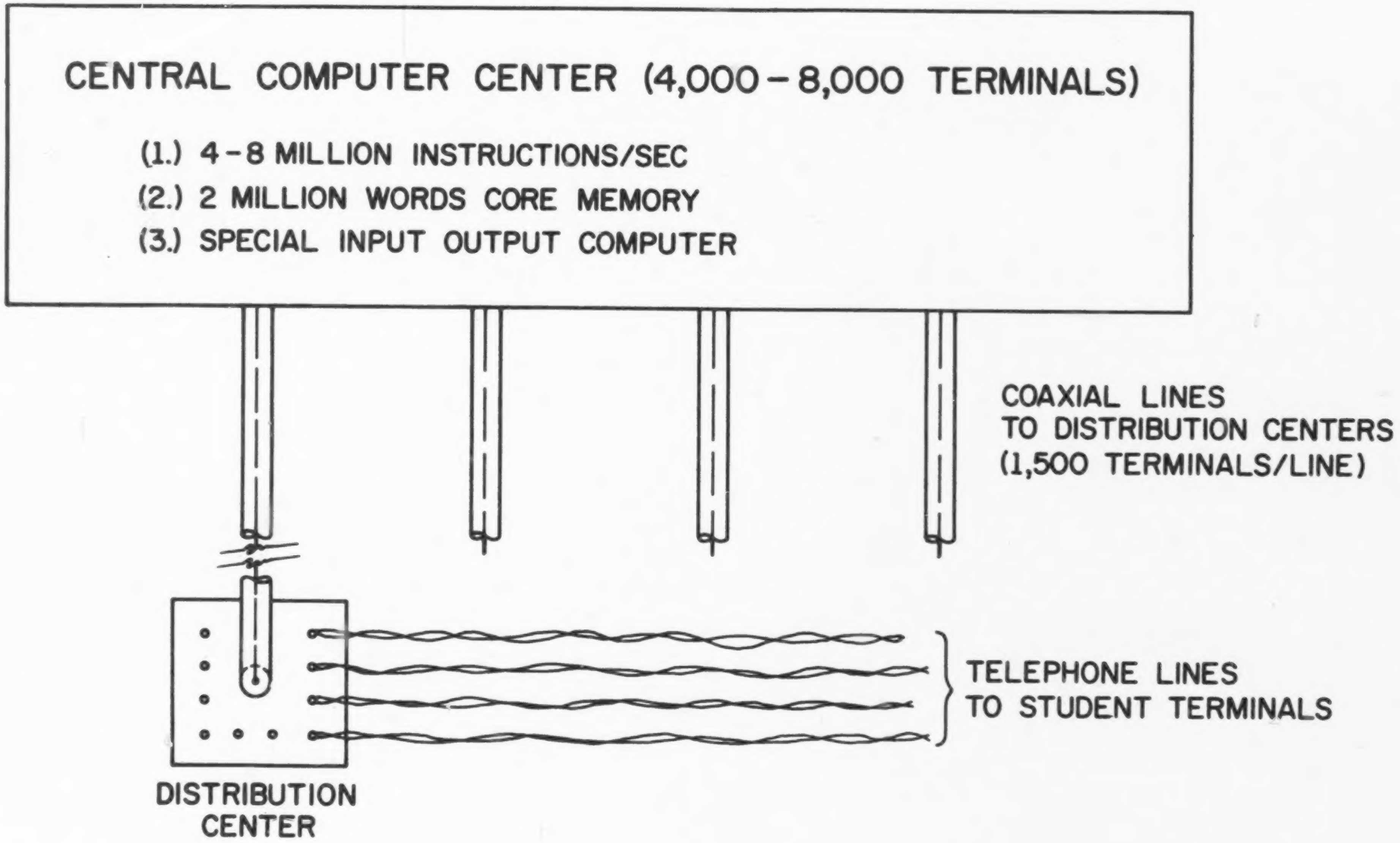

CENTRAL COMPUTER CENTER (4,000 - 8,000 TERMINALS)
(1.) 4 - 8 MILLION INSTRUCTIONS/SEC
(2.) 2 MILLION WORDS CORE MEMORY
(3.) SPECIAL INPUT OUTPUT COMPUTER
COAXIAL LINES
TO DISTRIBUTION CENTERS
(1,500 TERMINALS/LINE)
TELEPHONE LINES
TO STUDENT TERMINALS
DISTRIBUTION
CENTER

Fig. 10—Proposed distribution system

Table 1

SUMMARY OF COSTS

Item	Total Cost (millions of dollars)	Cost/Year[a] (millions of dollars)	Cost/Student Contact Hour (cents)
Computer and extended memory	4.5	0.9	8
Software	1.5	0.3	4
4000 student terminals	7.5	1.5	15
Subtotal	13.5	2.7	27
Lesson material	—	—	3
Data distribution lines	—	—	4
Total			34

[a] Five years' amortization.

CONCLUSION

Using newly developed technological devices it is economically and technically feasible to develop large-scale computer-controlled teaching systems for handling 4,000 teaching stations which are comparable with the cost of teaching in elementary schools. The teaching versatility of a large-scale computer is nearly limitless. Even while simultaneously teaching 4,000 students, the computer can take advantage of the 50 percent idle time to perform data processing at half its normal speed. In addition, 16 hours per day of computer time is available for normal computer use. The approximate computer cost of 12 cents per student contact hour pays completely for the computer even though it utilizes only 1/6 of its computational capacity. The remaining 5/6 of its capacity is available at no cost.

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THE TECHNOLOGY OF SMALL, LOCAL FACILITIES FOR INSTRUCTIONAL USE

Kenneth J. Stetten
The MITRE Corporation, McLean, Virginia

INTRODUCTION

Until recently, it was believed necessary to invoke the economics of large computer size to achieve cost economy of less than 40 cents per terminal-hour for highly interactive, fast, and effective CAI and CMI classroom service. The recent development of the TICCET system* (which stands for Time-Shared Interactive Computer-Controlled Educational Television and has been under development by The MITRE Corporation for the past three years) has shown that quite similar and, in some ways, even better classroom service can also be provided by a small computer—and at the *same* predicted cost per student. These costs represent an approximate cost reduction of 10 to 1 over a number of previous CAI/CMI systems.

In the TICCET system, a mini-computer located in the school building simultaneously serves 100 to 300 students with a new level of computer instructional service. This new computer system and the educational applications we are planning for it are the subject of this paper.

The factors that allowed development of a small computer system to provide such economical and highly interactive service were:

1. The recent price lowerings in the marketplace for small or mini-computers and their core memory modules.
2. Even greater price reduction for high-capacity disc drives and their controllers. In the TICCET system, these contain a very large curriculum of algorithms, lessons, data, and course structure.
3. The development and production of inexpensive and reliable television

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* For a detailed technical and cost description of the TICCET system, see K. J. Stetten, R. P. Morton, and R. P. Mayer, *The Design and Testing of a Cost Effective Computer System for CAI/CMI Application*, The MITRE Corporation, MITRE Report No. M69-39, Rev. 1, April 1970.

refresh devices.

4. A MITRE designed-and-developed breakthrough in data-transfer hardware which allowed the computer to send as much as one entire television frame of information (250,000 bits) every 1/30th of a second in synchronism with standard television scanning. This feat involved peak transfer rates approaching 16 megabits per second and use of integrated circuit logic modules in a design that had to take into account fractional nanosecond response.
5. A special software structure that allows the 100 to 300 terminals—an unusually large number for a small computer—to be served both with very fast response times and with very flexible algorithmic and data-retrieval service.
6. The use of an ordinary television receiver to provide computer-generated voice, pictures, and flicker-free text to the student.
7. An overall design philosophy that carefully delineated the required and *unrequired* functions for the system to deliver, and demanded engineering within tight cost boundaries.
8. The research results of many prior investigators in the fields of CAI and individualized instruction.

Although this conference is concerned primarily with applications of computers to higher-level education, I must note that the TICCET system was developed first to serve the nation's masses of elementary schools. I recognize that universities and colleges have a markedly different environment in many ways.

However, we have found that potential computer users from a wide spectrum of education and training institutions have shown great interest in the features and economy of the TICCET system, and also in the educational strategy which gave birth to it. Since we at MITRE have not fully explored the application of TICCET to higher-level education, it is my purpose to give you enough information to allow you to begin an evaluation of the place of the small decentralized computer system.

EDUCATIONAL GOALS

The primary educational goals of MITRE'S TICCET program are humanization, relevance, and individualization. In using these emotion-laden words, we have simple, specific meanings in mind.

By humanization, we mean enormously more one-to-one conversation between student and teacher. In elementary school, this is accomplished by the teacher walking around the classroom and pausing to converse with individual students. In the college environment, I would expect this might be compressed into private appointments with the instructor—say, one-half hour every three weeks.

By relevance, we have in mind not only hand-tailoring of the curriculum to the individual student, but also the result of greatly increased two-way communication with the instructor, i.e., feedback on designing overall goals of the curriculum. In my opinion, this is sorely missing from the college environment.

By individualization, we mean that each and every student progresses in his own style, learning mode, and rate in *all* subjects during the whole day— *whether* *or not* he is on the computer terminal. (It is our expectation that he is not on the computer during most of the day.) The essential characteristics of individualized instruction are:

- The student learns to teach himself.
- The educational materials become learner-centered.
- The student progresses at his own rate and in his own style.
- The instructor becomes a manager and a diagnostician instead of a lecturer or a dispenser of information.
- The instructor spends most of his time in *one-to-one conversation with students rather than always standing in front of the whole class.* The students are free to move about and to talk to each other about their activities (the college-level equivalent is the virtual abolishment of scheduled lecture periods) and they spend most of their time working by themselves.

HARDWARE DESCRIPTION

Figure 1 shows a TICCET terminal. The display is an ordinary, portable television set. The keyboard is a quiet, all-electronic keyboard laid out similar to a typewriter keyboard. This equipment is highly reliable, familiar to students and teachers, extremely flexible, and available at low cost.

Figure 2 is a simplified block diagram of the school-site hardware. The main computer is a "mini-computer" with 64,000 16-bit words of core memory. The mass storage is four disc drives having a total capacity of approximately 120 million characters. Input to the computer from the keyboards is concentrated through a much smaller (8K core) mini-computer.

The output to the television sets is provided by a device called a Television Display System. This system contains a character generator and a track of video disc refresh memory for each of the TV sets. These pictures recorded on the video disc are repeated at a rate of 30 times a second, the standard TV signal rate for refreshing TV pictures.

This same TV display system also serves as the speed buffer for the audio output to the headphones, resulting in a cost-saving factor of 10 over the use of core for this purpose. Audio messages are made up of computer assembled strings of digitized spoken words. The vocabulary of words is stored on the mass memory disc drives. A vocabulary of 5,000 words is anticipated as adequate. This vocabulary uses only about 10 percent of the mass storage space.

CURRICULUM GENERATION

In the elementary school case—where a large volume of material is entered by 30 to 50 people over a period of a year—curriculum data are generated on the authoring-site computer and then hand-carried to all the school-site computers. The school-site computers use this new, latest edition of the curriculum and generate performance data on the system and on the curriculum materials. These performance data are then hand-carried back to the authoring agency where they are

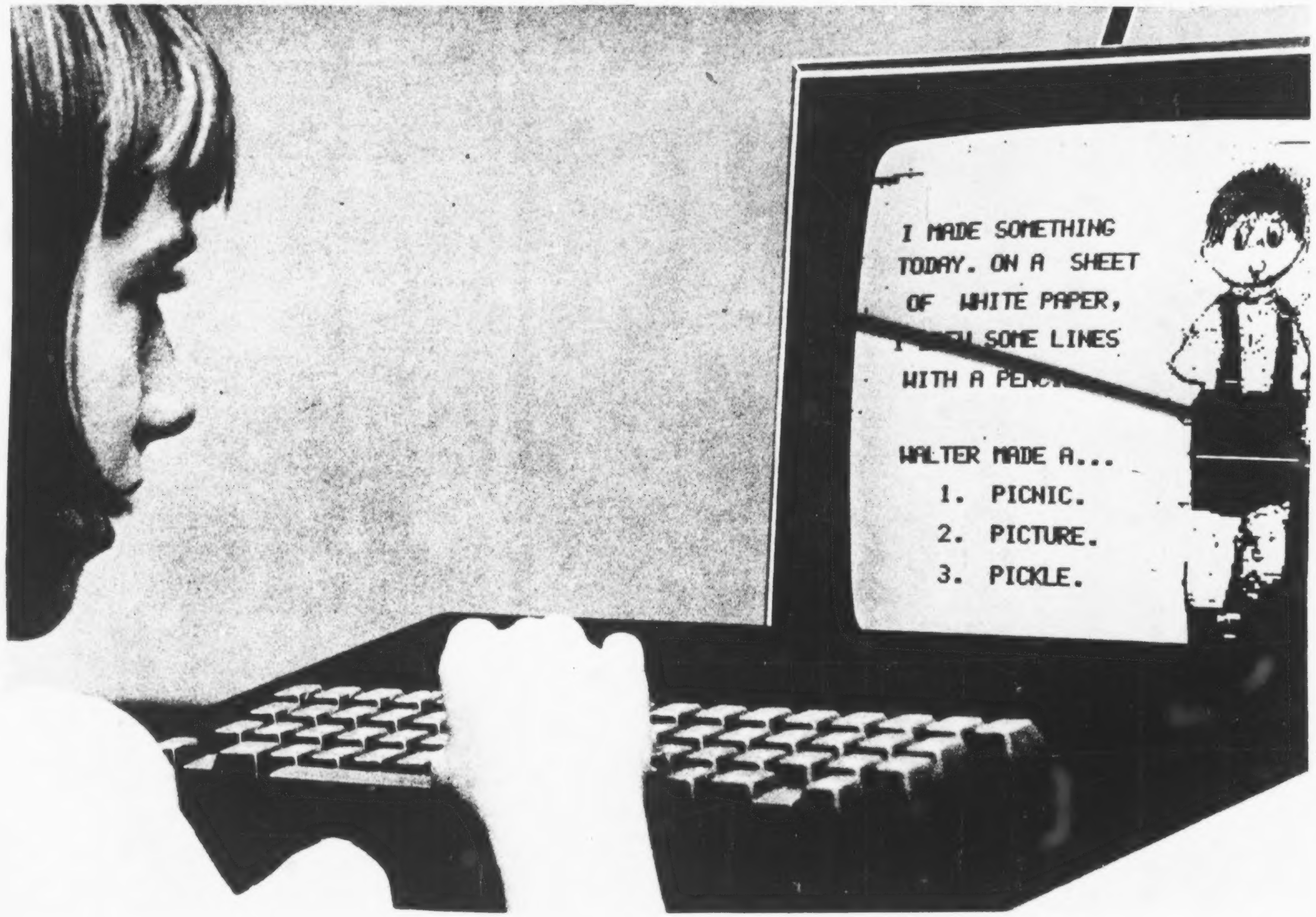
I MADE SOMETHING
TODAY. ON A SHEET
OF WHITE PAPER,
SOME LINES
WITH A PENC
WALTER MADE A...
1. PICNIC.
2. PICTURE.
3. PICKLE.

Fig. 1—A TICCET terminal (the display device is an ordinary, portable television set)

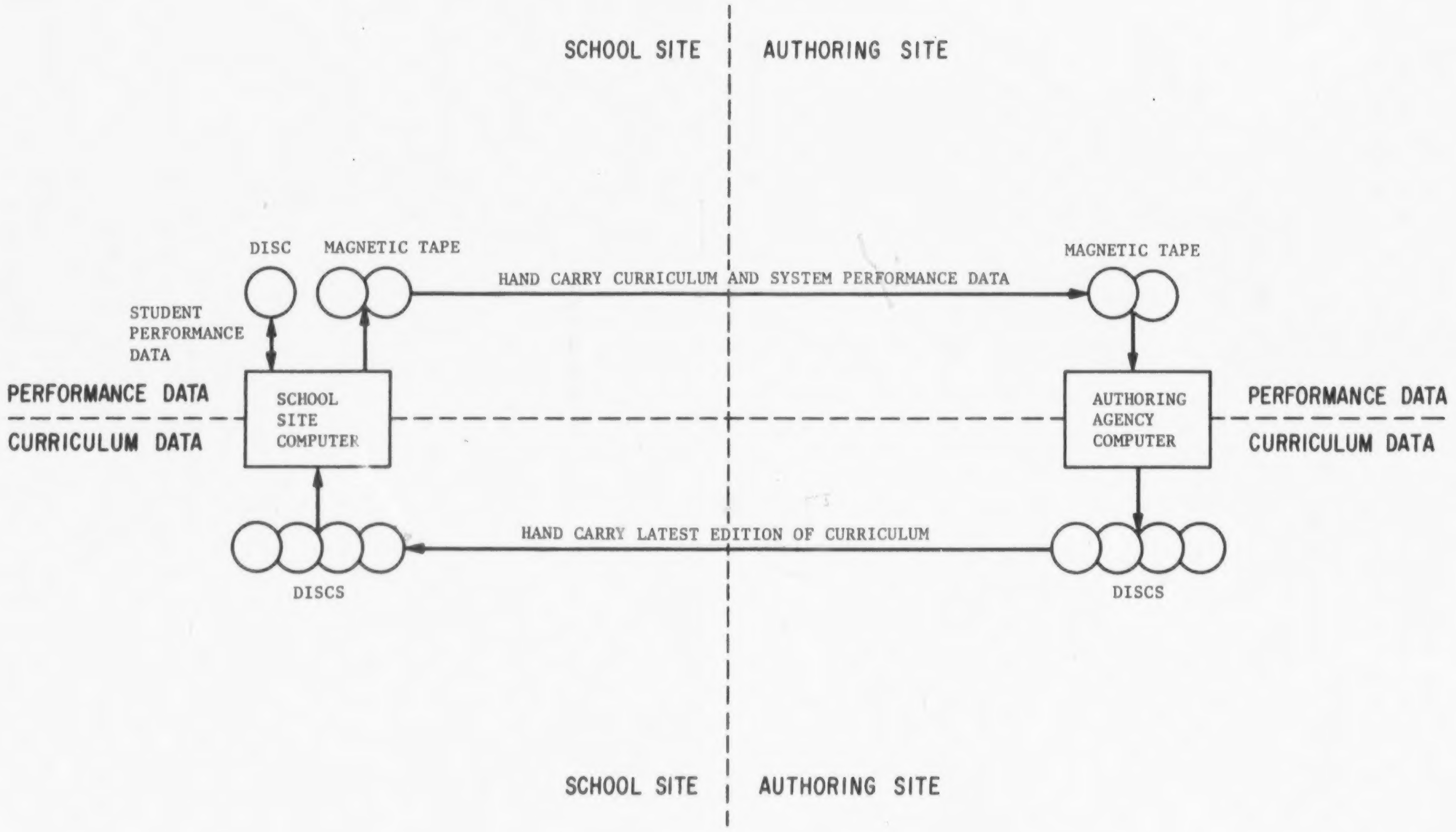
SCHOOL SITE
AUTHORING SITE
DISC
MAGNETIC TAPE
HAND CARRY CURRICULUM AND SYSTEM PERFORMANCE DATA
MAGNETIC TAPE
STUDENT PERFORMANCE DATA
PERFORMANCE DATA
CURRICULUM DATA
SCHOOL SITE COMPUTER
AUTHORING AGENCY COMPUTER
PERFORMANCE DATA
CURRICULUM DATA
HAND CARRY LATEST EDITION OF CURRICULUM
DISCS
DISCS
SCHOOL SITE
AUTHORING SITE

Fig. 2—Data base components showing feedback paths between school and authoring site

analyzed to find where improvements in a curriculum or even in the system programs can be made. Following this analysis, changes are made, the new curriculum materials or new computer programs are prepared, and the new edition is then disseminated to the schools.

In the higher-education environment, a variation on this approach is available. The TICCET school-site computer is adequate to serve both student and author needs simultaneously, since only a few authors are working at a time.

COST

For a school population of 1,200 students, 120 TICCET terminals would provide one hour of terminal service per day per student in a 10-hour day. Purchase price and installation of the TICCET system, amortized over an 8-year period, would be about $25,000 per year. The cost of maintenance and other incidentals, including curriculum royalties, add another $20,000 per year. Thus, the total cost for the TICCET system would be $45,000 per year, or about $40 per student per year or 20 cents per terminal-hour.

SUMMARY

The outstanding features of this TICCET system are the following: Recent advances in computer technology allow mini-computers to be both fast and cheap. This low cost with high speed results in outstanding cost-effectiveness characteristics. The use of ordinary television means that the display device is one that is universally available, proven, reliable, cheap, and maintainable. There are no hardware risks due to unknown production factors or the development of new components. The TICCET system has been designed from the beginning to be easily disseminatable.

The functions for which TICCET was designed are:

1. Administering tests.
2. Analyzing test results.
3. Prescribing remedial instruction or identifying the next step in instruction.
4. Identifying most effective paths and modes of instruction for individual students.
5. Identifying weaknesses in instructional content material and modes of instruction for feedback and course improvement.
6. Scheduling student use of instructional equipment and facilities to minimize student delay and maximize efficiency of plant utilization.
7. Maintaining student progress records in a form to optimize interface of instructors and students.
8. Presenting visual instructional frames with multiple paths to accommodate individual differences.
9. Providing speed and ease of operation, programming, and maintenance.
10. Providing student flexibility in choice of instructional material and mode

within limits prescribed by the author.

11. Providing motivational aspects such as quick response, clear image, relative silence, comfortable use features, high reliability, and accessibility on demand.
12. Providing programs (instructional and machine) designed to encourage maximum student effort.
13. Providing alarm to the instructor when the computer identifies student problems (exception reporting).

Comparing TICCET to large, dedicated CAI systems, we find that the minicomputer can provide to its 100 or so users essentially the same service that the large machine provides to its thousands of users. Our experience, based on a simulation model and mathematical analysis of the small computer system, shows that TICCET can provide each of 120 students with 60,000 instructions per minute of algorithmic service, and further, that all 120 students can be working on a different lesson. From the user's standpoint, the decentralized approach also allows a simpler management implementation of the system onto the campus.

Panel Discussion I:

WHAT WILL BE THE COMPUTER'S CAPABILITIES AND COSTS?

Rapporteur: F. W. Blackwell

Fred M. Tonge, University of California, Irvine

Fred Tonge expressed his uncertainty about whether there are economies of scale in either hardware or software. We especially need to produce software tools of all kinds.

Technology is not the answer to all our problems, either in education or elsewhere. We must develop some specialized systems, being careful in each case to get the right system: Let the application, not the technology, determine the system. Education by computer, in Tonge's view, is basically a good thing. In fact, we may have to automate just to get the job done; there won't be enough teachers, or sufficient high-quality instruction in problem areas.

In conclusion, he stated that if there is enough demand for good instruction —including instruction by computers—the problem will be solved by necessity.

Harry D. Huskey, University of California, Santa Cruz

Harry Huskey indicated that we must look at the whole system and ask fundamental questions like, What *is* higher education? How we regard it—as research, information-imparting, or whatever—determines how the computer fits in. We also need to have a perspective about computers and humans; we can make faster and bigger machines, but not faster and smarter people.

How to apply an appropriate filter in the information explosion is a big problem. This is a continuing process, because what is important and relevant often changes rapidly. Care must be taken that CAI software utilization does not become a rigid protocol, difficult to change. There is no excuse for this to happen, given the flexibility of even today's hardware and software.

Huskey expressed the opinion that decentralized operations will become increasingly important. Accompanying these will be personal data bases, easily transportable and accessible.

Other Comments

The panelists felt that hierarchies of programming language will become a viable reality. We will be able to define new languages rather easily, using mechanisms such as language extensibility and compiler-compilers.

There will be little functional difference in hardware and software. We will need people who are well trained in both, and emerging computer science curricula will hopefully give us such people.

Since it is virtually certain there will be *some* kind of CAI in the 1980s, we need to explore many different technologies and approaches in the 1970s. At present, small amounts of experience tend to be blown up as definitive, which is a serious mistake.

Above all, the computer should free us to try many instructional alternatives —not put us in an educational straightjacket. We can even use the computer to help implement the notions that education can be fun and relevant! The fear (by some) of computerized instruction should not blind us to the real opportunities. The computer should be viewed as a medium for users, not technologists. The technology is there but must be considered as only a tool, not a constraint.

Session II

HOW WILL COMPUTER SERVICES BE PROVIDED TO THE CAMPUS?

James B. Farmer, Chairman

The first paper in Session II was presented by William B. Kehl, University of California, Los Angeles. This paper was not made available for publication in the present proceedings.

THE COMPUTER IN HIGHER EDUCATION: A POSITION BASED ON PERSONAL EXPERIENCE

Peter G. Lykos
Illinois Institute of Technology, Chicago, Illinois

Several observations and recommendations will be presented here dealing with the computer and higher education. Because of limitation on space and time they will be given in highly simplified form. These observations and recommendations have been distilled from a variety of experiences which include the following:

1. A university computation center currently using one of the fastest scientific computers in the State of Illinois supporting administration, research, and teaching on IIT's campus, and 80 remote terminals in secondary schools, junior colleges, colleges, and universities in the greater Chicago area.
2. An academic program in computer and information science involving many students enrolled in undergraduate and graduate courses and including a new graduate degree program reflecting the increasing use of computers in secondary-school education, namely, a Master of Science for Teachers (Information Science).
3. A community service program operating continuously since 1961 whereby a Saturday program of courses for high-school students and workshops for teachers dealing with computer programming and computer applications has involved more than 15,000 students and 1,200 teachers from 300 high schools in the greater Chicago area. Starting four years ago, they have been given the opportunity to have an on-site computer experience from their own terminal for a total annual cost of $2,000, and many have taken that opportunity.
4. A regional program involving faculty from 14 junior-college, college, and university campuses grouped by the disciplines Biology, Chemistry, Business and Economics, Physics, Psychology and Education, Mathematics, and

Sociology, and using a common computer from remote terminals while trying to determine the relevance of the computer to the teaching of their curricula. This program is one of some twenty now in operation partially funded by the National Science Foundation.

5. Over the past two years, one to several one-day meetings with the computer policy committees (which included faculty, nonacademic staff, and administrative officers) in over forty junior colleges, colleges, and universities in the Midwest in order to discuss the role of the computer in their institutions and the attendant problems of faculty and staff training and of computer service.
6. A State of Illinois Board of Higher Education Data Systems Task Force concerned with administrative data processing in all institutions of higher education in Illinois including data bases, report formats, and supporting computer programs.
7. A State of Illinois Board of Higher Education study group charged with assessing the supply and demand of computer scientists and other professionals in Illinois for the next ten years. The recommendations of Committee Y included creation of an extended Master's degree program, Master of Computer Science and Administration (MCSA), to produce "doers" with training in computer and computer-terminal hardware and software, communications technology, operations research, and management.
8. A State of Illinois Board of Higher Education committee concerned with the thirty institutions of higher learning in the greater Chicago area and how they might enhance their individual efforts through cooperation. An Association for Instructional Resources Cooperation is now being formed focusing on Television, Documentation and its Dissemination, and Computers. The computer activity is concerned with sharing computer facilities, computer technologists, and computer knowledgeable academicians in a variety of disciplines.
9. A national network involving ten universities using graphics computer terminals accessing a common computer and supporting development of curricular elements in upper-division chemistry.
10. A working committee on Computers in Chemistry of the National Research Council, National Academy of Sciences, generating regional and national conferences and a National Laboratory for Theoretical Chemistry.
11. A conference held at IIT in January 1969, on the Impact of Computers on College Curricula, which drew 350 participants from 22 states.
12. A conference held at IIT in August 1970, on Computers in Undergraduate Science Education: Physics and Mathematics, which drew 380 participants from 31 states.

Based on the experience gained in those and other activities, the following observations seem worth noting:

1. Universities with graduate programs have developed substantive computer centers over the last ten or twelve years, and hardware and software configured to support graduate research. Federal support of those centers has fallen off

sharply over the past one to two years and those centers are undergoing agonizing reappraisals.

2. Administrative data processing has had a large influence on computer equipment selection and on computer service in secondary schools, colleges, and in those universities which did not have a strong graduate program ten years ago.

3. Public institutions usually have more sophisticated administrative data-processing systems than do private institutions. However, in any institution with both administrative data processing and educational computing, the latter is more sophisticated than the former.

4. Most people see the computer as supporting administrative data processing, graduate research, and serving the undergraduate program either as a super desk calculator or in some computer-assisted instruction capacity. Only very recently has there come the realization that the computer is affecting the way the problem-solvers and the decision-makers of our society work and that as a consequence our hard and soft sciences curricula need to be correspondingly *content* modified.

5. Most secondary-school, junior-college, college, and university computer services provide only token computer support for their students and are incapable, as presently organized, of supporting their student bodies on a broad-brush basis. Furthermore, such services as do exist are provided on an extracurricular catch-as-catch-can basis.

6. Very few secondary-school and junior-college faculty in the hard and soft sciences and in business have any training or interest in the computer and its effect on their disciplines (except for vocational data-processing education which is usually very basic and sorely lacking in standards, and except for use at the level of an electronic desk calculator).

7. College faculty, stimulated by the NSF Regional Computing Networks programs, seem to be the most active and concerned about discovering the impact of the computer on *what* they teach and on *how* they teach.

8. University faculty fall into two categories, tenured and nontenured. The tenured faculty generally got locked into their approaches to teaching and research before the computer became widely available, and generally leave the use of that tool to their graduate students and postdoctoral research associates. The nontenured faculty feel they earn no "brownie points" for innovation in the teaching of undergraduates and generally devote all available time to their research. Consequently, university undergraduate programs lag behind many of the college programs in reacting to the impact of the computer.

9. Mathematicians have very little interest in, or knowledge of, computer science and computer technology. They lag way behind those concerned with the hard and soft sciences in this regard. The layman's misconception that "computers is mathematics" has probably done more to inhibit the infusion and diffusion of the information-processing machine into education than any other single factor.

10. University and college computer-center directors come from either academic or data-processing backgrounds with little or no formal computer technology, management, or curriculum innovation and techniques training. Generally they are expected to provide effective management of a complicated facility based on a technology changing rapidly in time and drawing on an inadequate work force which lacks structure and standards. Generally they are expected to provide leadership

and guidance in computer applications in all academic and nonacademic areas. Generally, and understandably, neither expectation is met, the latter not met more frequently than the former. University and college faculty and administrators have abdicated their responsibility in this regard.

11. More and more secondary-school students will have acquired actual computer programming experience before they get to college and will come to college expecting to find the computer playing an active role in a variety of the academic curricula.

12. Most academicians and administrators see the information-processing machine as a stand-alone device (a "computer") which does calculations either locally or from a terminal. There does not yet seem to be an awareness that the information-processing machine is becoming an important complement to society's information repositories, information handlers, and communication network.

13. There is a growing concern and uneasiness about the creation of data banks, their use, and possible loss of privacy and control by the individual. There does not seem to be a corresponding awareness that the same information-technology system means that the individual can insist on a greater, more direct, and more immediate role in the decision-making processes affecting society.

14. Our knowledge about educational technology, about computer and communications technology, and about the impact of information technology on all areas of human endeavor is so incomplete and fragmentary that it would be highly inappropriate to commit higher education to *an* approach. Indeed, individual enterprise and variety need to be encouraged.

Finally we come to a set of recommendations:

1. Many of the best minds in the problem-solving and decision-making disciplines are doing research at the universities. "Reward" systems need to be invented in order that they can be induced to adapt the algorithms they develop in connection with their research for use in undergraduate teaching. Recognition of their successes in this regard must enter visibly in their advances in salary and position. Also royalty payments must be made for use of their "packages," both locally and elsewhere.

2. Faculty training is sorely needed at the secondary-school as well as the junior-college, college, and university levels in the impact of the computer on *what* they teach as well as on *how* they teach. Furthermore, what is known in this regard is likely to be in a state of flux and evolution for some time to come so this faculty training needs to be in the form of continuing education.

3. Courses and seminars and discussion sessions need to be developed and encouraged, addressing themselves to the impact of the rapidly growing information technology on society.

4. At least at the upper-division undergraduate level, the better students need to be drawn into the process of development of curricular materials based on use of the computer.

5. Administrative data-processors have no real feeling for the computing needs of the academician—and vice versa. This chasm needs to be bridged, for the academician will increasingly come to be dependent on, and be directly interfaced with, the student-record data base, at least, in his principal task as an officer of instruction. Additionally his department chairman, at least, will increasingly come

to be dependent on, and directly interfaced with, the personnel and financial data base. This objective is more likely to be realized if the management and academic sides of the house share the same computer facilities at least part of the time. There are other compelling reasons for such sharing.

6. Whatever local facilities exist need to have all aspects of their operation completely visible to representative members of the user community from both the management and academic sides of the house. These aspects need to include hardware configuration, operating system, charging algorithm, and the various services offered.

7. Commercially available computer services need to be examined from a hardheaded cost-effectiveness point of view as possible alternatives to other sources of computer service. However, commercial services cannot be attracted to the education market until education matures to the point where it defines what services it wants.

8. There needs to be developed an Information Processing Node (IPN) at each academic institution—or multiple such nodes in larger institutions—which takes advantage of recent developments in mini-computers and in computer-terminal and communications technology. In fact, such a system is under development at IIT (where it is called a Computation Laboratory) and the enclosed section of the Request for Proposal recently distributed (Enclosure 1) gives its essential features. The system is expected to function in four, possibly five, modes as follows:

A. Provide conversational computer support in a simplified higher-level language to a group of students on a classroom basis.
B. Provide conversational file generation and editing capability to a group of students, and have communication capability, so that the instructor may dial up computers elsewhere in order to use programs there in batch mode.
C. Provide a CAI system so the instructors can develop their own curricular supplements or components.

For those schools where financial constraints dictate that one information-processing node needs to support administration and education, the laboratory can function in at least two more modes:

D. Provide a data-processing-oriented language to support administrative data processing, and
E. Provide computer support for on-line control of an experiment.

Current technology is such that the cost of the hardware for the Computation Laboratory (including 32 terminals) is about $200,000.

In this fashion even those schools of modest size can have their own stand-alone facility together with full capability to access any other computer, anywhere, which is interfaced to the communication system.

In summary, the position taken here is that our colleges and universities must be free to pursue their own aims and goals as regards the impact of the computer on their management and educational processes. Accordingly, they need some local control and autonomy *as well as* the freedom to seek out and use whatever remote computer-based services they desire. It is in this sense that we support the notion of decentralized computing.

THE COMPUTATIONAL LABORATORY—AN OVERVIEW*

The computer is beginning to find an important place in college education. The influence is not restricted to the hard sciences, but extends throughout the curriculum. However, the use of computers has been only on a token basis, even at most of the large universities. Many of the smaller colleges still have no access to computers, since they are under the impression that meaningful computing involves large-scale expenditures.

It seems essential to incorporate the use of the computer into the curriculum in an orderly scheduled manner. It is quite unsatisfactory to attempt to extend the typical current systems, in which students contend for a small number of keypunch machines in their spare time.

We have therefore devised the notion of a Computational Laboratory, consisting of a classroom of terminals, into which students are scheduled as part of their standard program of study. This Laboratory would be used both for computer-based instruction and problem-solving sessions in a variety of disciplines.

The availability of low-cost mini-computer hardware makes the establishment of such a facility practical at relatively low cost. The mini-computer system can duplicate most functions of a large-scale system with respect to the requirements for student computing.

The availability of communications hardware allows the use of a variety of large-scale systems remote from this installation to handle more complicated problems. This latter approach is of particular importance, since the possibility of using application programs on the computer system for which they were designed allows the establishment of a direct link between the student in the Computational Laboratory and the frontiers of research in universities across the nation. It should also be noted that the concept of an on-site facility communicating with a variety of large systems at the convenience of the user is much more attractive than the more standard arrangement of a small machine which is "tied" to one large central computer.

The necessary software, further described in the next section, partially exists in a variety of systems. However, no currently available system provides the necessary software in an integrated package designed specifically for this purpose. It is the intention of IIT to generate the required software system, with a view to duplicating the Laboratory in a variety of colleges and universities.

Another important factor with regard to the use of this sytem in a small college is that it would be capable of supporting the administrative requirements if suitable software were available. Thus funds could be combined to put the system in reach of many small colleges.

No fixed cost limits have been established for individual components. However, a target cost of $200,000 has been established for the entire system (all items are to be purchased outright). Bids for individual subsystems should be made with this cost requirement in mind. In general, cost is an important factor, since the attraction of this system for small educational units lies in its flexible facilities and low package price.

SOFTWARE COMPONENTS

The basic system would be oriented to handling the visual-display terminals in a flexible conversational manner. A dynamic scheme for allocation of memory, using swapping techniques, would be required. A number of modules would operate independently to meet specific needs.

Desk-Calculator

In immediate, conversational mode, a desk-calculator language would allow rapid solution of simple problems. The calculator should have facilities comparable to a modern

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*** Part of a Request for Proposal distributed to hardware vendors by the Illinois Institute of Technology, Chicago, Illinois.**

electronic calculator including plotter output and programming capability. In addition, a full range of mathematical functions and complex arithmetic would be provided.

High-Level Interactive Languages

A variety of higher-level interactive languages would be implemented including a full implementation of the language designed at IIT for student use—IITRAN. IITRAN is a comprehensive language with excellent diagnostics which is ideal for most student applications. Another language to be provided would be a small version of SNOBOL-4, a string manipulating language of great use in the humanities disciplines. These languages would have the capability of executing conversationally, but compiling would be done on the basis of a pre-edited file being accessed (see The Text Editor, below).

CAI System

A system permitting preparation of CAI texts for a variety of courses by instructors would be included. This system would be oriented toward use by nontechnical instructors and would incorporate suitable text-matching techniques and use of disk storage for large scripts.

The Text Editor

Since visual-display terminals are to be used, the editing of files is primarily implemented by using the concepts of frame processing, employing the editing capabilities of the terminal itself. Thus it is unnecessary to learn a complex editing language, since the operation of the editing controls of the terminal is quickly understood by experimentation. A comprehensive file system allows named files to be stored on the disk storage device. Since the capacity of this device is limited, an important feature is the ability to remove and replace the disk pack. Thus the files for a particular class can be stored on a particular pack which is mounted at the start of a session. In addition, files can be permanently saved on magnetic tapes.

Remote Entry System

If students are to successfully use applications programs at various remote computer installations, they cannot be expected to learn several different systems of job-control language. The RIGEL (Remote Input Generator Language) system allows specification of the construction of job streams for remote runs incorporating student files and the necessary control cards. RIGEL also allows for analysis of the resulting output streams so that only relevant information is transmitted to the students. In normal operation, the instructor would prepare a RIGEL program for a particular application program. When the students had constructed suitable files, a system command would activate RIGEL and prepare a runstream for submission to the remote site. After the results had been received the runstream would be analyzed, and the relevant material returned to files from which it could be retrieved at the terminals.

Hard-Copy Output

A printer attached to the system would allow both the printing of the display image on a console, or entire named files could be printed. This would be used to obtain a hard-copy record of final successful results.

Data-Processing System

This package would be oriented towards meeting data-processing needs of a small college. It would include three components:

1. An RPG processor suitable for small-scale applications.
2. A sort/merge package for sorting disk files.

3. A small COBOL processor for more sophisticated applications. This would approximate ANS COBOL level 1.

It should be observed that the remote-entry facilities would also be available to meet these needs. However, there is usually a much higher confidence level in a local on-site system for critical applications such as payroll production.

HARDWARE COMPONENTS

Central Processor

A suitable mini-computer processor with at least 32K bytes of memory (=16K 16 bit words), together with necessary input-output and interrupt structure.

Fixed-Disk Subsystems

A small, fixed-head, random-access storage facility to be used for systems residence and program swapping.

Removable Disk Storage Facility

This is a moderate-capacity random-access storage facility used to store all working files. The capability of removing and replacing disk packs is an important factor in increasing flexibility, particularly for administrative use, and use in CAI applications.

Terminals

Thirty-two visual display terminals.

Printer Subsystem

A 132-column printer for use in administrative applications, and for hard-copy output from the terminals.

Card-Reader Subsystem

A low-to-medium-speed card reader to be used primarily in administrative applications.

Plotter Subsystem

An inexpensive paper plotter (probably of the X-Y variety), to be shared by the terminal users for output of graphical information.

Tape Subsystem

An IBM compatible tape drive for permanent file storage.

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THE ROLE OF REGIONAL COMPUTER NETWORKS

Gerard P. Weeg
Computer Center, University of Iowa, Iowa City, Iowa

We have been wrestling with the question of how computer services will be delivered to institutions of higher education in the next several years. Everyone is aware of how brief generations are in the computing field, making prognostications of even a few years duration a hazardous venture at best. However, if we work carefully from a well-developed base in present circumstances, we might catch a reasonable glimpse of the next four or five years in the field. Fortunately, I am to consider the future of regional computer networks; fortunately, I say, because regional networks seem to me to be such an eminently sensible way to deliver computer service to the many smaller colleges of our nation.

FORCES SHAPING OUR FUTURE COMPUTER NEEDS

Let us obtain a view of the institutions of higher learning as found in our nation today, and of the forces shaping their posture relative to computing. According to a paper of John W. Hamblen,* there are some 2,477 institutions of higher learning in the United States. A breakdown of these colleges by highest degree offered (Table 1) sheds some light on the nature of the schools in our country.

One can observe that there are 1,413 colleges whose enrollment is less than 2,500 and whose highest degree is the bachelor's degree or lower. Thus, far more than half the institutions which we will serve in the next few years will be of a markedly different nature from the 194 large doctoral-granting institutions. Generalizations are usually fatal, but the computing needs of the 1,413 colleges doubtlessly differ significantly from those of the 194 large institutions.

In common among large and small institutions is the need, which will become more pressing, to provide computing service for instructional and administrative

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* John W. Hamblen, "Computing Facilities in the Small Institutions: 1966-67," *Proceedings of a Conference on Computers in the Undergraduate Curricula,* University of Iowa, pp. 11.19-11.25.

Table 1

INSTITUTIONS OF HIGHER EDUCATION IN THE UNITED STATES (1966-67)

Enrollment	Highest Degree Offered: Associate	Bachelor's	Master's	Doctorate	Total	Total Enrollment, Fall 1967 (millions)
0-500	287	257	101	70	715	0.2
500-2499	343	526	196	101	1,166	1.5
2500-	143	48	211	194	596	5.3
Total	773	831	508	365	2,477	7.0

purposes. On the other hand, in general, the smaller colleges will not for some years have the same needs as the large universities in the use of computers in research studies, in analog-digital laboratory environment, in experimentation in CAI, or in a myriad of ways depending upon the sophistication of the peripheral equipment.

Probably underlying the computing needs of all institutions, large and small, is the need for raw batch-processing capacity. Among nearly all faculties already well-trained in batch-processing computing there is also found a sharp need for interactive systems, implying rapid response using fairly sophisticated systems. Since, however, there are few large schools offering the doctorate which have no computing facility (in John Hamblen's paper,* 72 percent of the schools granting the doctorate had computers on June 30, 1967), while those offering at most a bachelor's degree frequently have none at all (about 27 percent had computers on the same date), it seems reasonable to assume that the need of the majority of the "small" institutions will be for relatively unsophisticated use of a computer. This need will be primarily for instructional uses which, in general, will have received less attention than administrative data-processing uses.

Another force which will shape the needs of colleges and universities is the awakening of state governments to the double fact that their state universities are spending enormous sums of money on computing (usually with no wisp of coordination between sister universities in the many states having more than one state university), while many of their smaller state colleges not only have no computing capacity but do not even care. As a result, state commissions with near-absolute power over how computing dollars will be spent will be created. These in turn will seek the straight-away approach to providing computing for the small colleges while harnessing noncoordinated computer growth in the large universities. In many instances this will imply regional networks of smaller colleges connected to a large state university facility. In some instances we will no doubt see sophisticated nets of large computers at large state universities, more powerful indeed than that found at the Triangle University Computation Center (TUCC) complex.

One last major factor affecting the delivery of computing service to our colleges is the present state of funding. The large university centers are, in many instances, running their present general-purpose computer power up against its limit and will therefore in the next couple of years require major new investments in equipment. This takes place at the same time that state legislatures in a flurry of economy (and possibly punitive/retaliatory) moves are cutting state budgets for higher education. On the federal front, research funds have been curtailed which might otherwise shore up sinking computer centers and, in a final blow, that bastion of the university computer center, the National Science Foundation, has announced that it will no longer support computing facilities, with the notable exception of computing facilities proposed for cooperative interinstitutional purposes.

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* John W. Hamblen, op. cit.

Summarizing to this point, we see that the majority of the computer have-nots are the small colleges, who might reasonably turn to the neighboring large university for help in entering the computer maze. State governments will exert pressure for intercollegiate cooperation among their state institutions. Finally, the universities that seek NSF aid for expanding their facilities will certainly pay careful attention to that agency's policy of preferring to support cooperative development. All augurs well for cooperation between institutions in the next few years.

NETWORK ADVANTAGES AND DISADVANTAGES

With this prelude, consider now the regional networks in existence today. Largely because of enlightened encouragement on the part of the Office of Computing Activities of the NSF, some seventeen regional networks have been established or embellished in the past two years. These range in variety from fairly loose mutual-assistance pacts, as found in the Southern Regional Educational Board and the New England Regional Computing Center, to tighter combines such as the Dartmouth and Oregon State University typewriter network, to the very cohesive educationally minded group associated with the typewriter network connected to the Illinois Institute of Technology, to the fairly highly organized system of medium-speed and "intelligent" batch terminals found in the Iowa network. Outside this set of networks is the interuniversity network of sizable computers at TUCC. Thus, the range of typical networks includes

- Mutual-assistance groups with no hardware connection.
- Typewriter networks, with and without a high degree of central stimulation.
- Medium-speed batch-processing terminal networks.
- Intelligent (small computer used as a terminal) terminals.
- Large computers intercommunicating.

I know little about the last category, although we are slowly inching to that brink in our home state of Iowa. The mutual-assistance groups have been included in part in the presentation of my two predecessors. Allow me to dwell on the typewriter networks, medium-speed batch-processing terminal networks, and intelligent-terminal networks.

These three kinds of networks enjoy certain common advantages and disadvantages, and I may as well state them first. Assuming a network consisting of a large university using its general-purpose computing facility as the focus of a net of typewriters or batch terminals for remote colleges, there is first of all the basic problem of getting such an enterprise organized. In our own instance, I know we spent twelve months of intensive effort organizing a set of participating institutions, convincing our administration, and seeking funding, not to mention the hardware and software problems needing solutions. This then must be cited as one major disadvantage of a regional network. Others follow rapidly: the remote schools simply do not control computing on their campus to the degree they would if they had a local computer; at the same time, much of the computing time, systems effort, and administrative direction of the university center must be directed away from the university community which the center is pledged alone to serve. Logistical problems become crucial; having several vendors coordinate the installation or repair of complicated interconnected equipment can be a nightmare. Communication between the focal and the remote institution is overwhelmingly essential, but because of distance, may be difficult to provide. These are some of the obvious disadvantages of networks over stand-alone facilities.

But they are no match for the advantages, in the properly administered network. Perhaps chief among the advantages is the fact that with the proper planting of a terminal system on a campus, the college can catapult in a year or two to the level of computer use which universities achieved only after long years of often bitter experience. A small staff, commonly one or fewer full-time equivalents, at the college, is often all that is needed to sow the seeds of the computer doctrine. Availability of a massive program library, huge banks of memory, super-fast CPUs, and a large staff of systems and programming consultants are all pluses simply not available to the ordinary low-budget college with a stand-alone system. The fiscal and administrative organization of the terminal at the small college can be imposed by the university, thus allowing the small school to sidestep some blunders. It appears to be easier to prevent the computer use from being essentially preempted by the administrative data processors in the terminal situation than is the case with the stand-alone system. And finally, money is an advantage. Referring to the paper of Hamblen and Alcorn,* it is estimated there that the average small stand-alone computer system will cost an institution around $65,000 per year. My experience has shown that this figure is more nearly $100,000 per year. The ordinary terminal arrangement will generally cost less than $50,000 per year, even including the payments the small college makes to the central facility for computer time. Thus, the terminal system generally costs the small college less than a stand-alone system, while at the same time the financial base of the focal computer is broadened.

As would be expected, various kinds of terminal networks have advantages and disadvantages peculiar to themselves. Let me examine as briefly as possible a specific example or two of networks before I discuss what I perceive to be their important pluses and minuses.

Typewriter-Terminal Networks

Several excellent networks built primarily around typewriter terminals exist today. Allow me to show a few features of just two such networks, those centered at Dartmouth College and at Oregon State University. Each has received significant support from the National Science Foundation, but both would probably have existed in some form without the aid.

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* John W. Hamblen and Bruce K. Alcorn, "Some Alternatives for Providing Computer Facilities to Small Colleges," *Proceedings of a Conference on Computers in the Undergraduate Curricula*, University of Iowa, 1970, pp. 11.13-11.18.

Dartmouth College Regional Consortium. The Dartmouth Consortium was established in 1968 upon the base of an already well-running time-sharing system created at that school. I will restrict my attention to the NSF-funded consortium, in view of the accessibility of data concerning it. Some logistics:

Dartmouth College Computer:

GE 635
- 100K words (36 bits)
- drum
- 6 disks
- 1 IBM 2314
- 2 GE Dataset 30

Operating System
- Dartmouth Time Sharing System
- 1 background job stream

Software
- BASIC
- FORTRAN
- ALGOL
- sophisticated file system

Participating colleges are shown in Table 2.

Thomas Kurtz, director of the Kiewit Computation Center at Dartmouth

Table 2

PARTICIPATING COLLEGES IN DARTMOUGH COLLEGE REGIONAL CONSORTIUM (1966-69)

Institution	Enrollment	Air Miles to Dartmouth	No. of TTYs	Phone Line
University of Vermont	6,500	70	0[a]	0
Norwich University	1,200	37	2	1
Middlebury College	1,500	49	3	1 MPX line
Vermont Technical College	500	25	2	1
Colby Junior College	580	26	1	1
New England College	1,000	44	1	1
Berkshire Community College	1,000	100	1	1
Mt. Holyoke College	1,700	73	5	1 MPX line
Bates College	1,000	107	4	1 MPX line[b]
Bowdoin College	1,000	117	4	1 MPX line

[a] University of Vermont established its own stand-alone system.

[b] Bates and Bowdoin use the same multiplexed phone lines.

states* "The exact number of terminals needed [to establish critical mass] depends on the precise nature of the way computing is used. . .. We have found generally that at least two terminals are needed, and considerable slack time on them is needed to encourage new uses and additional faculty involvement."

An overall summary of usage in Dartmouth Consortium (1968-69) is as follows:

Number of users	6,483
Number of terminal hours	19,017
Total CPU hours	69
Total computer charges	$46,279
Computer charges/terminal hour	$2.43
Average users/month	61
Average terminal hours/month	1,701
Average terminal hours/user/month	3

In the years 1969-70 some of these key averages had changed to:**

Average percentage of terminal time used	11.8
Average cost/terminal hour	$4.81
Average terminal hours/user	8.22
Average cost/user	$39.55

Finally, one member institution of this network, Mt. Holyoke College, reported that its total expenditures for participation for one year (1970-71) are estimated as:***

Salaries	$ 6,200
Equipment	2,500
Line rental	3,600
Computer time	15,000
Total	$27,300

Oregon State Regional Computer Center. This network was begun in 1968 with NSF support, as a continuation and expansion of earlier pilot projects. The NSF-funded portion of that network again occupies my attention.

Oregon State University Computer:

CDC 3300/PDP-8
- 81K words (24 bits) memory
- 5 disk units
- 200 million byte mass storage disk
- communication MPX
- PDP-8 as interface to TTYs

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*Thomas E. Kurtz, "Dartmouth College Regional Consortium," Chapter 3 of *A First Report on an Exploratory Program of Regional Cooperative Computing Activities*, the Oregon State University Computer Center, 1970, pp. 45-52.

**E.A. Fucci, *Comments for the Regional Consortium* (Interim), Dartmouth College, August 1970.

***Richard A. Groeneveld, "Experience with Various Alternatives," *Proceedings of a Conference on Computers in the Undergraduate Curricula*, University of Iowa, 1970, pp. 11.26-11.41.

Operating System

OS-3 (Oregon State Open Shop Operating System, a locally developed time-sharing system)
1 batch stream

Software

FORTRAN compiler
ALGOL compiler
COBOL (conversational arithmetic interpreter)
COMPASS (CDC assembly language)
RADAR (on-line debugging language)
EDITOR (on-line text editor)
SORT/MERGE
utilities package

Participating colleges are shown in Table 3.

Table 3

PARTICIPATING COLLEGES IN OSU REGIONAL COMPUTER CENTER (1968-69)

Institution	Enrollment	No. of TTYs	Connect Hours	CPU Hours
Oregon College of Education	3,700	2 ASR 35 3 ASR 33	1780	16
Portland State University	11,000	2 ASR 35 3 ASR 33	1853	17
Eastern Oregon College	1,700	2 ASR 35 3 ASR 33	1030	18
Southern Oregon College	4,450	2 ASR 35 3 ASR 33	547	3
Oregon Technical Institute	1,400	2 ASR 35 3 ASR 33	528	2
Lane Community College	5,500	2 ASR 35 2 ASR 33	1150	7
University of Oregon Medical School	950	6 ASR 33		

The communication system used involves multiplexing all TTYs at one school onto a single modem, thence to a high-speed phone line (300 to 3000 baud). Moreover, more than one school is multiplexed onto the same phone line in two instances.

In the OSU Regional Computer Center Year-End Report to the NSF an analysis of the ratio of connect hours to CPU hours and to log-ons (Table 4) provides information about the average terminal session length.

Table 4

CONNECT TIME STATISTICS AT OSU (1968-69)

User	Average Terminal Hours/Month	Average CPU Time Hours/Month	Average Log-ons/ Month	Average Terminal Session Length (minutes)
Students	439	3.5	1731	15
Faculty	167	1.4	669	15
Total	605	4.9	2430	15

The cost of all computer time used by the OSU network in 1969-70 was reported as $42,000.*

Medium-Speed, Batch-Processing Terminals and Intelligent Terminals

Only a few networks using batch terminals exist. Since one is centered at my own institution, I will discuss the batch terminal network as found in the Iowa Regional Network.

University of Iowa Regional Computer Center. This Regional Computer Center was established in 1968 with NSF support, and like the other two networks, it was built on an earlier start of modest size. The terminals used are IBM 2780s and two IBM 1130s. An IBM 2780 is a card reader, line printer, with rated speed of 300 cards per minute and 300 lines per minute. Driving the IBM 2780 over 2000-bit-per-second lines actually produces about half that speed.

University of Iowa Computer:

IBM 360/65
- 768K bytes memory
- 2 IBM 2314
- 2703 data communication adapter

Operating System
- OS-MVT-HASP II (Release 18, as of July 1970)
- 6 job streams
- CPS conversational system

Software (available to 2780s and 1130s)
- FORTRAN IV G and H
- ALGOL 60
- JOVIAL
- Assembler
- CSMP/360
- GASP
- SNOBOL III and IV
- SLIP

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* Larry C. Hunter, and Jo Ann Boughman, *Report on OSU Regional Computer Center Project, July 1, 1969-June 30, 1970,* August 3, 1970.

COBOL F
GPSS/360
SIMSCRIPT
IPL-V
LISP
FORMAC
SORT/MERGE
WATFOR
PL/1
PLC
Assembler G
RPG
SNAP-500
MPS/360
MARVEL
ECAP 360
DYNAMO
PLOT
GPLOT
PMS/360 (PERT time and cost)
ICES/360
MATLAN
LPLOT

Participating colleges (1969-70) are shown in Table 5.

Table 5

PARTICIPATING COLLEGES IN UI REGIONAL COMPUTER CENTER (1969-70)

Institution	Enroll-ment	Air Miles to UI	Ter-minal	Phone Line	Cards and Lines (millions)	CPU Hours	Total Year's Cost to Colleges
Iowa Wesleyan	825	50	2780	(a)	2.7	9	$50,000
Kirkwood	1,279	23	2780	(a)	.6	2	20,000
St. Ambrose	1,270	56	2780	(a)	1.4	4	29,000
Central	1,285	100	2780	(a)	3.5	12	43,000
Clarke	982	70	1130	(a)	.7	7	53,000
Coe	901	23	1130	(a)	.5	2	17,000
Marycrest	1,100	56	2780	(a)	1.4	3	30,000
Loras	1,460	70	2780	(a)	1.3	3	35,000
Grinnell	1,056	62	2780	(a)	4.1	13	45,000
Augustana	1,896	52	2780	(a)	2.5	9	46,000
University of Dubuque	1,048	70	2780	(a)	.5	2	20,000

[a] Leased line 2000 baud, 2,201 data phone.

The percentage of utilization of the terminal ranged from 28 percent at Grinnell College to 3 percent at the University of Dubuque, with the average percentage utilization being 11 percent. This is computed on the total time the terminal was used compared to the number of hours available in a two-shift operation.

The two intelligent terminals in the system, the IBM 1130s at Coe and Clarke Colleges, were installed prior to the creation of the network, each for a different purpose. The 1130 at Clarke was installed principally to support a Computer Science Department and other academic activities. The 1130 at Coe has been principally used as an administrative data-processing tool with relatively less emphasis on academic processing. Given the local power of an 1130, both schools looked to UI for only the most sophisticated computer uses.

Some of the advantages and disadvantages of typewriter-, batch-, and intelligent-terminal networks are listed in Table 6.

Whither Regional Networks?

We have so far looked at the forces acting upon colleges, which appear to be conducive to interinstitutional cooperation. The merits of networks relative to other means of delivery of computer service were presented, with the conclusion that in at least some instances, networks are more feasible than stand-alone systems. The various kinds of networks were typified by a few examples, and relative merits again set forth.

It seems to be a highly reasonable assertion that regional networks hold the promise of producing computer understanding and use on campuses formerly devoid of both with greater efficiency than any other means. Yet I am a bit pessimistic about the future of networks. The outcome of the dozen and a half networks funded by the NSF is still in doubt; how many networks will remain in robust condition now that the funding has vanished for most of them is not clear. Should many continue, then the future of networks looks bright. As a state casts about for ways to coordinate computer growth among its institutions of higher learning, if the consultants whom the state hires to propose a solution can have the example of several really viable networks, I would believe that networks might indeed be proposed.

A network involves several things: staff, communications equipment, computer hardware, software, terminal equipment, and a great deal of urging on by some enlightened individuals. Key to the success of a network is the delivery of a system that works from the instant of installation. Hence, I foresee that any regional network will continue to focus at a large educational institution which has had massive experience in producing computing satisfactory to its constituency. Newly created conclaves centered about an up-to-then nonexistent computer center would appear to be facing insurmountable troubles.

The networks will require a coordinator on each campus who is dedicated full-time to the furthering of computing in education. As this ideal recedes, the chances for success diminish.

Communication equipment constitutes a huge part of the expense of a network. Believing that most networks will be intrastate, larger reliance on bulk service, namely, WATS in and out lines, together with a reasonable way of sharing these lines, will be used to equalize communication costs while not dampening the enthusiasm of the user.

I believe that schools with no previous computer experience will be better served starting initially with remote batch terminal facilities. As sophistication and funding increase, these will be supplemented by interactive systems, plotters, card scanners, and other attractive peripherals.

In order to give the terminal the broadest possible base, enough time must be relinquished from academic usage to encourage the administrative staff to do its data processing. This will be encouraged by the staff of the focal computer center who will provide direction, assistance, and program packages and services.

As computer usage increases, there will naturally be a demand to establish a local computer center. Care to prevent a rape of academic computing must then be exercised.

Table 6

RELATIVE ADVANTAGES AND DISADVANTAGES OF TYPEWRITER-, BATCH-, AND INTELLIGENT-TERMINAL NETWORKS

Advantages	Disadvantages
Typewriter-Terminal Network	
Easily learned languages are usually available	Slow response can be discouraging to user
User can concentrate on a relative few languages	Number of terminals is critical (must be at least two per small college)
Interaction is psychologically rewarding	User is presented a narrower variety of computer languages and services
Redundancy of terminals prevents down-time	Line costs for multiple lines build up
Lends itself to CAI	Slow printer limits kinds of output practically available
Low cost	Difficult to use for administrative data processing
	Can accommodate only about 4 users/hour—hence only 64/two-shift day/typewriter
Batch-Processing-Terminal Network	
Massive set of languages and services	Unpredictability of turnaround
Same access to batch as if a large computer were on campus	High cost of terminal and line
More students can be served without increasing basic cost	No interaction
More readily adapts to administrative data processing	
Can expand to TTYs as sophistication warrants	
Can attach other equipment, e.g., CRT, plotter, card scanners	
Intelligent-Terminal Network	
More local control	Requires more and better staff
Perhaps cheaper line cost, since more can be done locally	Costs much more
Properly controlled, turnaround can be superb	If the administration captures the intelligent terminal, academic use suffers severely
Easily adapts to ADP	

Finally, as networks reveal themselves as workable and cost-effective, large neighboring universities may indeed seek to cooperate on their computer development. The network at TUCC and among the Michigan Universities may presage such development. As I mentioned before, preliminary work in that direction is developing in the state of Iowa. It appears that large computers, nearly saturated because of huge and growing loads, can be successfully interfaced via high-speed lines to a larger computer. The gain in throughput will be immediate, and the gain in concept will be revolutionary.

In summary, I am convinced that the logic of regional networks is unassailable. In no other way can formerly computer-ignorant campuses be brought to useful computer awareness with such efficiency of cost and people. The dedication and drive of a large university center can be made to bear on a small college campus, channeled by a local coordinator filled with little else initially than enthusiasm. In the span of as little as a year such a campus can be electrified with computer zeal. With such terminals being planted by an academic center to further academic computer use on the small campus, the faculty will be sufficiently attracted to be able to withstand the natural impulses of the administration to withdraw that tool to their exclusive use.

Logic, however, is one thing, and incentive, another. The establishment of such networks is a work of such magnitude that some external force is imperative, in general, to set the chain of events leading to the creation of a network in motion. To submerge on one side of such a morass without knowing how or if one will emerge on the other side needs an incentive of more than ordinary size. Obviously one incentive is state legislative pressure, a force as yet not quite known. The other serious incentive is at least seed funding by Federal agencies. This latter force simply can not vanish for the next several years, at least until state forces crystallize.

THE ROLE OF COMMERCIAL TIME-SHARING SERVICES

Clint deGabrielle
Computer Education Institution, Inc., Raleigh, North Carolina

To properly assess the role that a commercial time-sharing service can play in serving the needs of higher education, it is first necessary to examine what such a service can offer that will be beneficial to an educational user. I don't believe that there is any single or simple reason that would prove attractive to all potential educational users. Rather, I believe that the individual situation which an educational institution faces at any given point in time may very well dictate its course of action in regard to computer services. These individual situations seem to be composed of a wide variety of elements—some physical, others emotional, and still others political in nature. The situations seem to be constantly changing as the cast of characters change, and very few three-or five-year plans tend to be implemented as originally conceived. Against this background, then, let us examine what I must admit is a biased view of the application of a commercial time-sharing service in serving the computer needs of educational users.

First, it is necessary that I state a definite prejudice in favor of student use of time-sharing. This is a posture that has been established over the past five years, watching sixty colleges and universities and over one hundred fifty high schools expose students to time-sharing terminals. Whether the student makes use of the terminal as a remedial device, as a manual work saver, or as an outlet for the ingenuity of an active mind, the mere fact that he can use the terminal at any time of the day or night and any day of the week makes his use of the computer more personal, and in most cases, more rewarding. I sincerely believe that interactive terminal usage of computers is by far the best student use of computers. Time-sharing will not satisfy all the computer needs of a school, but it can serve the major portion of student and curriculum needs.

With that commercial for time-sharing in general behind us, what factors of a commercial time-sharing service warrant our attention? A potential user of time-sharing needs to examine and relate various elements to his own needs. The first of these elements is hardware. The commercial service, and in all instances I am referring to a large, national-based service with adequate resources, tends to have a large and flexible system of hardware. The competitive environment forces the commercial service to provide large-scale core memory in order to handle more users; it must also provide substantial random file capacity for bigger and better files, and facilities for handling a wide variety of terminals. This permits the user to write larger programs, to use larger data bases, and to make use of the terminal device best suited to his particular application. In many instances this total capacity is not economically justified in a noncommercial environment. Since the commercial service must depend on reliable system operation for its revenue, it tends to provide power supply and adequate hardware backup to insure maximum uptime. Except in rare instances, the commercial service supplies more and larger hardware.

Having briefly considered hardware, the next logical area to look at is software. With the present tendency on the part of computer manufacturers to charge separately for software and software support, it may well be that the commercial service has a significant advantage in these two important areas. In order to be most attractive to the marketplace, the commercial time-sharing service invests heavily in software developments. Since they are continually running races with other services in order to secure business, they strive to make their compilers and languages more efficient than their competitors'. As a new feature is deemed desirable, they implement it in order to get an edge on competition. Commercial services have contributed significantly to the extension of computer languages and have also developed an impressive number of user-oriented subroutines and packages. This software is stable; it is used daily by thousands of users and bugs do not exist for long, since they affect revenue and require an undue amount of customer handholding. A commercial service should have the resources to supply more and better software.

After hardware and software the next major ingredient in a time-sharing service is the communication facilities. The commercial service normally has a network that makes use of bulk circuits, submultiplying, concentration, and switching. Multispeed, multicode, and multiformat terminals are serviced and multilocations are given access to the same files and programs. In general, the communication circuits and computer end data subsets are provided on a no-charge basis. Such an arrangement allows terminals at satellite locations to share a system with a main campus, and permits the school to expand the locations it can consider serving.

Next in line for consideration is a broad area called user services which encompasses a general library, both resident on the system and on the shelf, user class libraries, program development, newsletters, user groups, user meetings, user accounting, training, and data bases. The larger commercial time-sharing services are capable of developing between 100 and 200 new programs a month. The general library, which is resident in the system, will contain 300 or 400 application programs. In addition, there will be several hundred subroutines covering a broad spectrum—math, statistics, finance, science, engineering, text-editing, data-preparation, business, and industry requirements. The commercial service has available academic programs whose theory has been applied to a real-life situation. It also has available many programs used in the business environment to solve specific problems which are useful in exposing students to the methods used in solving everyday problems.

Commonly used data bases such as Dow Jones and Standard and Poors Indexes, demographic statistics, industrial data, advertising data, financial data, and employment data are stored and maintained. The capture, editing, and storing of these data are all part of the commercial service and can relieve a significant workload when compared to a school's own facility. With sixty or more colleges and universities contributing programs, ideas, and suggestions, the commercial service should and does prevent a great deal of reinventing on the part of educational users.

I would not suggest that an educational time-sharing users group cannot be organized by a manufacturer or a group of schools, but to the best of my knowledge, one of only two such groups that exist at the present time was organized by a commercial service. It has a monthly newsletter, annual meetings, a library service, and a referral service. It also has nearly 3,000 programs developed in the academic environment. These are pretty good credentials for service to the education community.

The area of consumer accounting may be one that is not really given its full share of credit. On one commercial service it is possible to provide an accounting structure that defines not only the individual use of the time-sharing service but any analysis above and beyond the individual, including class, course, frequency of use, time of day, and point of use. This analysis, coupled with student achievement profiles, should provide a clue to the benefits of time-sharing for a student, for a course, for a professor, or for a particular topic or segment, the frequency of use by a student, and the time of day used. The elapsed time from assignment, and the time prior to required date for return of assignment, are other items that are captured and displayed. On a strict dollar-and-cents basis there is also a breakdown that can show the cost per student, cost per assignment, cost per course, and cost per teacher. This isn't a function reserved to a commercial service, but it currently exists and does not have to be invented. In addition, the commercial service collects every possible statistic on system use, thus automatically providing a source for any analysis the user desires.

Sooner or later anyone considering his own time-sharing system has to consider two very significant requirements: first—space to house the system; and second—the staff to support and operate the system. Let's examine the space requirement for a moment. I haven't been on many campuses lately where space is not at a premium. It seems that there is a lack of dormitory space, classroom space, laboratory space, library space, administrative space—you name it—there is a lack of space for it.

A time-sharing computer center requires a modest amount of physical space. However, it also requires an environment that is quite different from and more expensive than the environment required by the human body, represented by the students and faculty. It might very well be that the money required to provide computer facilities could better be spent on other needed space for a school.

Most of you are aware of the salaries that computer systems analysts, computer programmers, and computer operators command. The present shortage of these types of people is not going to improve significantly in the next few years. Add to this the fact that adequate time-sharing, executive, compiler, and communications systems people do not exist and you have an added reason for anyone experienced in time-sharing to hold out for even more money. I know that undergraduate and graduate students and faculty have accomplished some remarkable feats in developing and supporting time-sharing systems, at very attractive salary levels. It is also very apparent that such support manning does not provide the type of continuity required to operate a quality service. Sooner or later you must hire a staff, and when that happens you must pay the going rate for time-sharing professionals. At this point you might very well create a problem as far as salary administration is concerned. It is a bit difficult to justify paying a time-sharing-systems man considerably more than most department heads, and certainly much more than the average faculty member. But perhaps this is not really a problem and therefore should not be considered an advantage for a commercial time-sharing service. I am sure, however, that the financial comparison of a commercial service and a school's own facility is of major importance.

I cannot stand here and tell you that there is any easy way in which to make this comparison on a strictly objective basis. The hardware supplier, the ambitious, empire-building data-processing manager for a school, and the status-conscious Dean can all make a sound case for their own system. Given my own assumptions and generous latitudes, I too can make a very strong case for the commercial time-sharing service. When all the pros and cons are weighed, then I honestly think that the financial picture is a toss-up. I know there aren't many of you that will agree with this view, but it stands to reason that if a commercial service has 10 computers to the school's one, 600 communications lines to the school's 60, 20 concentrations to one, 200 channels of multiplex to six, produces 5,000 manuals a year to 1,000, has 3,000 terminals installed compared to 300, then there have to be some economies involved that allow the commerical service to compete favorably with the costs of an on-campus facility—and still make money.

Add to this the fact that the majority of student use, as opposed to in-class use, can be scheduled after 5 p.m. and on weekends, and you arrive at a very attractive use of the installed facilities of the commercial system. If you further distribute the load by taking advantage of time zones, then you have an interesting situation to motivate a commercial service to make it financially attractive to an educational institution.

Oh yes, I almost forgot—the more college students that are exposed to time-sharing in school, the easier it is to sell time-sharing. So for very selfish reasons the commercial time-sharing community is very interested in developing the educational market.

As I said before, I am not sure that any of you will agree with me that a commercial time-sharing service can be financially attractive, but if it is not quite as attractive as a school would like can the school overlook: no need to provide space; the unsettling influence of the support-staff salaries; extended and up-to-date hardware; the best software at no cost; extensive academic program libraries; a close association with the "real world;" a nationwide communication network; free clerical assistance to maintain mailing lists, to supply programs, to handle a user group, to organize meetings, to publish a newsletter, to handle referrals, and to take on those little tasks that constantly erupt; quality documentation; free training; a flexible system to accept peak loads; a built-in market for graduates; someone else to blame problems on?

If I haven't made a strong case for the commercial time-sharing service to supply all the time-sharing services for a school, then I think a school should consider a commercial service to supply overflow or peak load service, service to remote locations or for meetings and seminars, a source for programs, use for special purposes such as meetings or seminars or for a special data base, software development, special training service, and facility management.

And so ends our discussion of commercial time-sharing services. Time-sharing is not the sole solution to the computer requirements of a school. Time-sharing does provide, in my opinion, the very best student use of a computer. Commercial time-sharing using a flat rate, unlimited-use approach to charging for its service can bring to the educational community a service which can be budgeted and which can provide the user with the best of two worlds.

Being with you this afternoon has been a pleasure for me. And I hope some of the information I've passed on has been helpful to you.

Thank you very much.

Panel Discussion II:
HOW WILL COMPUTER SERVICES BE PROVIDED TO THE CAMPUS?

Rapporteur: W. B. Holland

John Hamblen, Southern Regional Education Board

John Hamblen concluded that the speakers had come close to identifying the real problem: people. Communication with faculty and administration is the most important need of the campus computing world. Faculty and administrators must be made aware of the problems of and constraints on the use of computers.

He noted that the afternoon's speakers had not identified any one approach to the provision of computing on the campus as the absolutely correct one. He regretted that the speakers had failed to define what they meant by "centralization" and "decentralization" of computing facilities.

With respect to regional networks, Hamblen asked if we have really identified the needs of different types and sizes of institutions. He suggested that a proper examination of this question might lead us to realize that even the mini and small computers have a place for instructional purposes, especially for supplemental instruction. They could also be used for relieving overloads on large machines. As questions for thought, he suggested that perhaps we should consider hardware decentralization on the campus, even going so far as to consider giving each department its own small computer.

Dan R. Burgess, Control Data Corporation

D. R. Burgess suggested that small systems are economically inefficient and that the computer-facility concept is the way of the future. Each user will have access only to a computer facility, not to his own computer. He suggested that there is a great excess of computing power available today, and that one way that universities could get out of their current financial binds would be through bartering services for computing (time-sharing) power. Universities have talent and expertise that could be useful to the manufacturers, and time-sharing costs on the campus could be reduced by taking advantage of this latent resource.

The brief discussion period that followed served only to emphasize the concern of many in the audience for the financial problems of maintaining an adequate level of computing on campus and for improving campuswide understanding of what computing is all about.

Session III

HOW WILL INSTRUCTIONAL MATERIALS BE PROVIDED?

William F. Sharpe, Chairman

COMPUTERS IN INSTRUCTION—PREPARATION OF INSTRUCTION MATERIALS BY NONPROFIT CONSORTIA

Harold E. Mitzel
The Pennsylvania State University
University Park, Pennsylvania

My assignment today is to present the case for the preparation of computer-oriented instruction materials by nonprofit consortia. The background I'll draw upon for insights and generalizations about the development of curriculum materials is based on one recent intensive 2-1/2-year experience with a four-member group of institutions. Such an experience based on one consortium is of course wholly inadequate for the needs of the day and for charting new policy directions which this conference hopes to do. On the other hand, the application of computers to education processes is extremely new and as responsible professionals we must feel our way forward on the basis of whatever data and experience are at hand.

One source of irrelevance in my remarks is the fact that our CAI *Consortium* experience at Penn State has been focused on preparation of mathematics materials at the secondary-school level. I am aware that the thrust of concern at this conference is on computer use in higher education. As a staff member of a university college of education, I get to, indeed seem to be required to, keep one foot in the school and the other in the college.

I'd like to divide the balance of my remarks into three parts, first a description of one nonprofit, computer-assisted instruction consortium, then a few generalizations based on living within a consortium for 2-1/2 years, and finally a set of advantages and disadvantages inherent in a policy of encouraging computer-based curriculum development by nonprofit consortia.

The Commonwealth CAI Consortium is made up of the School District of Pittsburgh as participant and fiscal agent, the School District of Philadelphia, the Pennsylvania Department of Education, and the State University. The program of the group, which began in March 1968, is funded from resources provided under Title III of the Elementary and Secondary Education Act. The objective of the

Consortium since its inception has been to construct, evaluate, and implement in two urban high schools a completely individualized program of instruction in mathematics for ninth-grade pupils. In Pennsylvania every ninth-grade pupil takes either algebra or general mathematics. Hence these two courses were chosen for development in order to sample the full range of student ability in four-year urban secondary schools.

From the beginning, the plan of the Consortium was to use the computer as *a part* of the means to implement an *individualized* and maximally pupil-adaptive program of instruction. All of the instruction under the program was to be individualized, with the computer providing only a portion of the necessary interaction between pupils and curriculum. This point has proved to be very difficult to make in describing our program. Once you mention a role for the computer in an education effort many laymen make the assumption that all human contact with pupils has been withdrawn and the kids are cast into the maw of a monster. The lack of understanding of the subservient role played by the computer in our program also influences expectations of interested parties as to the generalizability of the evaluation results. In no sense should our results be considered as a "critical trial" for the idea of computer-assisted instruction. Empirical results of the kind we are obtaining depend upon a host of varied and uncontrolled program inputs which I cannot take time to enumerate here.

The operational plan of the Consortium is a three-step sequence, the first two of which are approximately complete: First, a curriculum development stage with the specific objective of preparing 50 to 60 clock-hours of material for an average pupil in each of two mathematics courses; second, a field trial and revision stage; and third, an operation-evaluation stage. We began last month on the operation-evaluation stage in Lincoln High School, Philadelphia, and in Schenley High School, Pittsburgh. The field trial was conducted during 1969-70 on approximately 100 students in these same schools with a computer and eight terminals in each school.

In order to understand the curriculum development of the Consortium it is necessary to review the utilization plan for the two-course program. The key concept of the program is *individualized instruction* with no compromises. Each classroom at both schools is equipped with 60 individual study stations, and 60 ninth-grade pupils are assigned to that classroom during each of eight 45-minute periods. Thirty of the stations are computer terminals on an IBM-1500 Instructional System, and 30 stations are designed for individual study with a variety of noncomputer-mediated subject material. Thus the curriculum material can be divided into two parts: an "on-line" part, meaning that portion which is mediated by the computer, and an "off-line" portion, referring to the correlated noncomputer self-study materials used individually by the pupils in the classroom. For this latter category some stations are equipped with filmstrip viewers, workbooks, textbooks, puzzles, and games.

With 30 computer terminals and 60 pupils at a time you can see that the program calls for an average "on-line" time of about one-half period per school day, per pupil. Let me emphasize that this must be an average period because of our determination to cater to individual differences in task completion time. The on-line course material has been carfully constructed to follow the state syllabi for both general mathematics and for algebra, and in this sense the "on-line" course materials contain the fundamentals of each course of instruction. The corresponding "off-line" materials are primarily in the category of enrichment, but we have on occasion included drill-like exercises where these seemed to be useful. "On-line" and "off-line" instruction for any given pupil are correlated by provision of messages on the screen of the cathode-ray tube at the end of units. These messages give the teacher and the pupil three option levels for related "off-line" experiences. Option A is selected if the pupil has traversed the unit quickly with good performance on the unit exit test. Option B is selected if the student has performed less well on the unit exit test, and Option C directs the student to "off-line" review materials with considerable help from a teacher or teacher aide. To assist the teaching staff to monitor performance of every pupil, a daily summary of performance from the student-record area of computer storage is printed at the completion of each day's instruction.

To complete the picture, let me add a note about the staff and the computer equipment. At the present time a staff of six adults serve every class of 60 pupils in the Consortium program. There is a teacher/manager, two certified associate teachers, a computer systems manager, and two teacher aides. The latter are student teachers from Penn State. Each student station connected to the IBM-1500 system is composed of a cathode-ray tube with keyboard and light-pen response capability, and an image projector, all under program control.

Now what have we learned from this experience that would influence a new curriculum development design?

First, the decision to directly involve teachers from the participating districts in the preparation of "on-line" materials and the selection of correlated "off-line" materials was wise. Four teachers, two each from the participating schools, spent 18 months collaborating with Penn State mathematics educators and technical staff in the preparation of "on-line" material. The knowledge of mathematics brought by the teachers to the task was not great, but they did bring an understanding of the motivations and sociocultural backgrounds of urban high-school students which was not possessed by any other group in the Consortium. After their extensive 18-month participation in curriculum development on the campus, the teachers were able to return to their home districts and operate the field trial and evaluation phases of the program as they were designed.

Second, teachers and college professors worked diligently on the preparation of computer-based curriculum materials even though they knew that the materials would be placed in the public domain. One of the possible criticisms of federally subsidized curriculum development by local consortia is that the developers lack incentive because no royalty payments are in the offing. We found no evidence to support the myth of low staff motivation because of the absence of a royalty for creative curriculum development.

Third, it is not easy for schools to change from conventional mass education practices to genuine individualized programs of instruction, even when the funds for development and implementation come from outside sources. The problem stems from a deeply entrenched philosophy of education which emphasizes competitive pupil marks, a fixed curriculum, and a concept of the role of the teacher as both judge and dispenser of knowledge. We found considerable resistance to the notion that anyone except a fully certified teacher could help a pupil learn in the classroom, or that bright kids ought to have different and more difficult objectives set for them than for average and dull pupils. There was a marked tendency among some school

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personnel to try to subvert the individualized program of instruction in the design by creating a new lockstep around the computer terminal. We called it the platoon system, with one-half of the class on the terminals for the first 20 minutes of the period and the other half on the terminals for the last 20 minutes. Such a plan conserves teacher energy and seems fair-minded to a group of adolescents, but a little experience showed that it is not conducive to learning to merely exchange the textbook-oriented lecture-recitation lockstep for a computer-mediated lockstep.

Fourth, there is widespread disagreement among equally well-qualified mathematicians and educators about the appropriateness and validity of a detailed mathematics curriculum such as that provided by 50 hours of "on-line" course work. Our experience has been that mathematics experts can frequently agree on a brief syllabus or outline. They still agree in large measure after the syllabus has been translated into a detailed set of behavioral objectives. But, when the objectives have been further translated into an individualized instruction sequence they frequently take exception to this or that treatment of the subject matter. A CAI program is, in the vernacular, "all hanging out" and subject matter experts seem to be more critical of the treatment in the CAI product than they are of textbooks and other media. This is a problem that will have to be faced by computer-based curriculum-builders whether they be in private industry, in development organizations, in committees of the learned societies, or in nonprofit consortia.

Fifth, school districts have the best chance of capitalizing upon a CAI development project and of eventually implementing the concepts into their regular program when they open up the project to significant interests in the power structure. It is almost axiomatic that schools have evolved as prime examples of "steady-state" organizations. New ideas, like computer-assisted instruction, threaten that equilibrium and for this reason it is essential that parent groups, evaluators, curriculum designers, media specialists, school nurses, personnel officers, administrators, and teachers all be encouraged to remove the implicit threat of change by familiarization. In our experience the students and the teachers have been the most effective ambassadors for CAI with the other constituencies. I suppose the same generalization holds for colleges.

In conclusion, I would like to list for you a set of advantages and disadvantages associated with the development of computer-based instruction materials by nonprofit consortia. These items do not necessarily stem directly from consortium experience, but seem instead to reflect my view of the state of the art as of this week. Among the advantages are the following:

1. Nonprofit consortia can produce materials more nearly tailored to the specific needs of the individual members than seems to be possible for commercially oriented organizations. This advantage of course disappears as consortia become large, enrolling more and more school groups.
2. Nonprofit consortia can produce enough materials in the early stages of CAI implementation to create a market for commercially prepared material which appears later in easier-to-understand-and-use packages.
3. Nonprofit consortia can produce computer-based material for small but important educational applications, say, the mentally retarded for example, in those instances where there is insufficient risk capital to back a commercial curriculum development.

4. Nonprofit consortia can produce small or large courses on specific subjects to fill particular localized needs without worrying about putting together a solid series that will match a competitor's product. Exercise of this advantage makes it possible for nonprofit groups to assemble the best pieces of computer-based material from a variety of sources and to fill in gaps with high-quality material of local origin.
5. There is a history of nonprofit education consortia in the United States which can be drawn upon for guidance and for administrative know-how. This history resides largely in the school study council movement and in the broadcast television groups now functioning around the country. There seems to be no reason why the organizational format could not be expanded to colleges, junior colleges, and technical institutes.

Now for some of the disadvantages of a policy which encourages curriculum materials to be produced by nonprofit consortia:

1. Nonprofit consortia typically do not have the packaging, warehousing, marketing, and service organizations needed for efficient widespread distribution of curriculum materials.
2. Nonprofit groups have to depend upon the grants economy with subventions either by the federal government or by foundations in order to provide the necessary development capital to create and disseminate new materials. The recently emerging educational laboratories and university-based research and development centers seem to fall into this category.
3. The lack of a profit motive encourages nonprofit consortia to hold onto their products for tinkering and the making of minor improvements beyond a point that is either desirable or necessary.

I'm sure the discussion groups will generate additional pros and cons for the production of curriculum material by nonprofit consortia. For my own part I'm quite optimistic that a "modus vivendi" can be achieved that will permit all interested and competent interests to participate in the instruction revolution offered by the computer.

WHO SHOULD DEVELOP INSTRUCTIONAL MATERIALS FOR CAI?*

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The question to which this paper is addressed is, is it necessary or desirable that a specialized organization, whether it needs to be established or already exists, be the focal point to produce instructional materials relevant to the use of the computer in higher education? The answer is yes, and is based upon two premises: (1) That as currently conceived, the time that a university professor spends in learning how to interact with the computer and how to take advantage of its capabilities and in fact in producing materials to be administered at a terminal generally comes about as an adjunct to his normal teaching requirements and other administrative duties. Thus, it is a part-time, secondary or tertiary effort that he gives to the problem of instructional material construction in this regard. (2) The very nature of the problem of exploitation of the computer capabilities involves a totally comprehensive and new look at the world of education in its entirety as a system if we are to exploit the capabilities opened up by means of this electronic device. The areas of expertise required are indeed multidisciplinary. Furthermore, the specialized organization with these disciplines available permits a perspective much broader in scope and much more useful than the narrow view which may come about as a result of a subject-matter scholar himself attempting to develop these materials or such a scholar in combination with a group having a commerical interest in turning out a product for a profit such as a publisher. I see the profit-oriented company as inappropriate to the task. By its very nature it inevitably is involved in a conflict of private versus public interest.

The fact is that nonprofit research and development organizations do not have a particular vested interest and some, such as HumRRO, have had a history spanning a number of years (19 in our case) of improving on the instructional development for one user by means of both helping him to see that what to teach is equally as important as how to teach it.

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The concept and techniques of task analysis had its roots in, and has been used effectively for decades by industrial and military organizations. Perhaps herein lies at least a partial reason for its lag in adoption by the educational establishment. But with the term, "programed instruction," this same engineering process—which involves the careful determination of objectives, development of tests to measure those objectives, and successive try-out of materials until students learn from them—has become more palatable. This engineering of the design of instructional systems for training has also benefited from complementary strategies developed to improve the organization of the materials for presentation (Shoemaker, 1960). For example, placing the materials in a functionally outlined context to represent instructionally in microstructure the tasks as they are eventually to be performed in the larger, end-of-training context has proven quite beneficial and also serves to screen irrelevant subject matter from courses of instruction.

In like manner, let us look to the situations our students will face after they leave college and begin working to define the performances they must develop while a student.

The techniques of computerized job analysis which Christal and his associates have developed (Morsh, 1965; Archer, 1966; Harding and Downey, 1964; Morsh, Giorgia, and Madden, 1965) can determine with considerable precision the most commonly performed tasks, can cluster position descriptions into job types, and can determine how jobs differ when occupied by people of differing experience. I should point out that these procedures have been developed by organizations of specialists outside the educational institutions. However, the detailed procedures are all available for finding out the demands for job-oriented higher education (Smith, 1964). Also available are methods for specifying objectives precisely (Mager, 1961; Ammerman and Melching, 1966).

If we are dealing with liberal-arts courses, similar techniques could be applied, as Dr. Smith has pointed out (1964), although with less precision.

The effort to develop objectives by looking outside the educational institution can lead to revolutionary changes in instruction. Previous HumRRO research reports instances in which instruction has been shortened by half and yielded higher levels of proficiency as compared to the then-standard course. The key has been analysis of required job behavior and the learning tasks involved, appropriate course design, and improved organization of instructional materials based upon diagnostic evaluation and repeated redesign to achieve desired effectiveness and efficiency.

Both the *what* and *how* aspects of instruction become even more important because of expense, complexity, and potential of the system involved when a computer is to be used in the instructional loop. One of the most pressing needs in the field of instructional development involving the use of the computer (whether it be drill and practice or other adjunctive uses on up through tutorial) is some commonly accepted basis for determining costs. Preliminary experiences at various educational institutions (see Bunderson, 1970) clearly indicate the wide variety in production costs per hour of CAI instruction. These figures sometimes are as much as three to four times greater from installation to installation and, clearly, at least some of the variation stems from differences in the complexity of the materials produced, use of revision costs in the analysis, inclusion of evaluation, inclusion or not of development costs for languages, systems and authoring techniques, etc. A recent statement by the director of a leading university-based CAI laboratory is worth quoting at this point.

> Based on the experience gained on these and other projects, we see how many costly aspects of development could be reduced by the application of better management, design, and production techniques and better CAI languages and systems. There are certain irreducible human costs for management, authoring, and evaluation-revision which cannot be automated, however, and for which there appear to be no dramatic shortcuts. (Bunderson, 1970)

The question concerning the role of the computer in producing materials can be asked in another way. Does one wish to progress in the field of instructional development by an approach which is basically a trial-and-error, small-scale attempt to incorporate the computer within the current folklore of instructional development? Or will we recognize the need to fully exploit the capabilities of the computer within a changing environment of instructional development and administration? If the latter, then the specialized organization is a desirable candidate. The investment will be much greater in dollar resources required, and in personnel required, but the payoff can be much, much greater in terms of the development of a new educational system than in the case of the former.

Why do we need the specialized organization? For one thing the talents required do not reside in any given department within a university. For another, as indicated above, talents that do exist in multidisciplines to attack the problems of developing material require a full-time effort. Whether one creates a specialized organization to handle the development of instructional materials or whether one turns to an already existing structure for such an organization, it nevertheless requires the full-time talent of subject-matter scholars, behavioral scientists, computer-science specialists, and hardware experts (Seidel and Kopstein, 1970). Moreover, existing reward structures in universities do not support repetitive product improvement with respect to course materials (e.g., publish-or-perish requirements, departmental dogma, etc.).

A summary of the obstacles found in one university installation when attempting to introduce some CAI materials for needed prerequisite skills indicates the following:

> 1. The lack of a cost-effective, service-oriented terminal facility.
> 2. The problem of grafting on an individualized, adjunct course to the lock-step, tightly scheduled course structure of universities.
> 3. The lack of fundamental interest and incentive of teaching assistants and other faculty in meeting the basic needs of freshman students. (Bunderson, 1970)

This is not surprising to anyone who has lived within a university. The departmental and disciplinary structures do not lend themselves to crossing these lines to promote interdisciplinary collaboration. Finally, even if such interest could be created there would be no interest in achieving compatibility of the computer-based materials with computer installations at other universities. The lack of interest in compatibility—a crucial but widely ignored problem—derives from the lack of incentives for widespread dissemination of the instructional materials. This holds for the potential receiving institution as well as the sender.

Our own CAI development effort has been intensely aware of the need for, and the current lack of, compatibility among existing CAI installations. Our basic motive as in the case of all nonprofit institutions is the public good. Our rewards are contingent upon the maximization of product quality and the widespread recognition of this fact. Our organizational survival is contingent upon the continued acceptance that we have served the public good and have served it well.

The next topic to discuss is, what are the resources required in order to accomplish the goals of instructional development using the computer? Again many of you will have heard the argument that computers are getting very, very, very inexpensive and that one can purchase such a device for on the order of a few thousand dollars. This may be very true and may indicate the fantastically efficient development of electronic technology. However, instructional technology is nowhere near developed to that point (Seidel, 1969 and 1970). Before I go on let me say that I do thoroughly agree with the value of having a creative faculty member muddling, making trial-and-error, and coming up with a fantastically innovative way to teach something in his field by allowing him to have all sorts of free contact with the computer and a terminal. By the same token, the creative graduate student is not to be ignored. However, these efforts lead to serendipitous benefits which cannot be reliably depended upon and should not be the focal point for the emerging of an instructional technology that is to take advantage of the capabilities of the many disciplines that can be brought to bear in improving instructional systems.

The issue is precisely serendipity versus professional reliability in instruction. There is no question that the teacher-scholar is to be found within the university or college. But he should be allowed to function as a full-time instructional designer. And this can be best accomplished in an organizational structure established to accommodate this. For, in the long run, will the quality of the products of a single person's expertise exceed those of an interdisciplinary professional team with competence in the psychology of learning, the mathematics of models and their optimization, information science, technical writing, and visual presentation?

It is difficult to perceive the profit-oriented company as an appropriate structure for such a development effort. Why? Because the profit-making organization is structured to serve the stockholder, gain annual income, sell products, etc. Unlike the university, the commercial publisher is indeed intensely interested in the wide dissemination of materials produced by him and in their prolonged use. To achieve widespread dissemination he would have to pay attention to compatibility. However, the continuing survival of the commercial house is contingent upon a simple fact of life—high frequency of excess of profit over loss. If one looks at the experience with programmed instruction, one finds a reluctance on the part of commercial publishers to invest in costly cyclical or long-term product developments. I do not think at present one can buy very many commercially published instructional programs for which adequate performance data are available and which have been frequently revised and improved in terms of diagnostic indications from such data. It is not unreasonable to assume that CAI will follow the pattern of PI.

Unlike the profit-oriented company, the nonprofit has no vested corporate interest in product sales. It works to solve problems in the public domain. Thus, it is most likely to facilitate mass *dissemination* of the materials to many users. In making the case for the nonprofit developer of CAI material, I cite again the history of organizations like HumRRO which have dealt with users of instruction. HumRRO teams have dealt with the traditional subject-matter experts explaining to them in great detail and repeatedly the value of stipulating one's objectives in not only behavioral terms but in terms relevant to the context of the job that the student was to enter following his training. I should add that all of the research products are available in the public domain (see HumRRO Bibliography of Publications, 1969). Now I know all the reservations that people will have concerning the similarities and dissimilarities between education and training, but for the moment let's put those aside. The point I am making here is that while teachers today, as well as trainers, have become aware in most instances of the value of stating behavioral objectives, they have not done this in isolation. Furthermore, the field of education has found that although this awareness may exist, there is a great deal of failure to take advantage of the knowledge that both *what* to teach and *how* to teach are equally important.

An interesting illustration is the large-scale study going on now in Texarkana where both the *what* to teach and *how* to teach are fantastically different from what was known to be the vogue or the customary practice. When it was discovered that incentives used for teachers and students were not the normal or traditional incentives, or the accepted way of rewarding, providing reward structure for students and teachers alike, many of the traditionalists became upset. But the point of the matter is it took an outside organization which specialized in the developing of instructional materials to propose these radical ideas, to view the situation from a different point of view than the field of education and the board of education and its traditionalists had viewed it. Some of the problems publicized recently may also illustrate the difficulties when a profit motive is introduced. I don't wish to take sides, but profit needs may be coloring either the user's perspective and/or the developer's. Incidentally, although the contractor is being dropped the program will continue. The case applies well to the use of the computer for instructional purposes whether one is going to use it for drill-and-practice mode, problem-solving, simulation, or tutorial CAI.

One final point I wish to emphasize once more is the need for adequate *evaluation* whenever instructional materials are developed. Here again it seems as though the structure of the educational institutions today is geared more towards a classic grading system, based upon normative approaches to measurement, and based upon extrinsic and perhaps irrelevant indicators of achievement. A's, B's, C's, etc., are not readily translatable into degree of achievement of specified objectives. Furthermore, they do not take into account the need for more appropriate diagnosis of individual students and the distinct possibility that all students should achieve 100 percent and receive A's in any given course they may be teaching. Changes are beginning to take place. Some universities and colleges, and some professors within a small number of colleges are becoming aware of the necessities for objectives, diagnosis, evaluation, and revision of course materials to enable all students to achieve to the maximum. However, this is no more than a very limited occurrence at present. On the other hand, there is within existing specialized, instructional development organizations a vast amount of capability and experience in this type of evaluation.

One possible candidate for accomplishing this type of evaluation, perhaps a reasonable model to use for the establishment of a different type of specialized and still nonprofit organization, palatable to policy-makers and educators alike, would be the establishment of experimental stations, such as proposed recently (by Rothkopf in testimony before the Subcommittee on Education) (see also Bunderson, 1970). Analogy is made to the agricultural experimental stations established to provide for planned analysis, evaluation, and improvement in understanding in that area. Right now education can be viewed as a high labor-intensive area and low-yield. Making instructional practices and activities explicit, and providing for the use of the computer within such experimental stations to aid in the improvement of instructional transactions, might well be a means for long-term involvement of the computer in production, evaluation, and dissemination of improved instruction.

At this point it is worth noting a caveat from my colleague, Dr. Smith, to all of us who are engaged in CAI work. His admonition is to avoid CAI parochialiam.

> My casual impression, which I hope is wrong, is that people working in CAI have a tendency to get so involved with their terminals, interfaces, operating systems, and other hardware and software problems, that they forget that there is a great deal of sound research in psychology and education which has a bearing on the engineering of instruction. I have just been reviewing this literature, and I am very impressed with it.

In other words, in our enthusiasm for developing better instruction we may tend to get too close to the computer to see beyond the peripherals.

To summarize, I have tried to state the case for a nonprofit special organization as the candidate of choice for developing CAI materials. The most salient points of this argument have been the fact that universities are not basically mission-oriented. Their organization and mode of operation do not lend themselves to instructional product development. Faculty members engaging in such efforts do so on a part-time basis and in competition with higher-priority concerns. Also, universities and their faculties tend to be relatively self-centered and have no incentive structures or interest to promote compatibility and widespread dissemination for their instructional products. While commercial publishing houses have such interest, their profit-making necessities mitigate against expensive cyclical product developments aimed at maximizing instructional effectiveness. Because the nonprofit, special organization's mission orientation, internal organization, and reward structure tend to serve this end, it is proposed as the proper type of candidate.

In conclusion, lest we think that our problems today are rather unique and novel, let me leave you with the following quote:

> There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things.

This, of course, was stated by that well-known educator, Machiavelli.

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COMPUTER-ORIENTED INSTRUCTIONAL MATERIALS

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My talk is not concerned with computer-administered or -assisted instruction, but rather with computer-*oriented* curricula in which computer usage is assimilated into the discipline itself. I think this is a crucial distinction; because, whereas the case for CAI as an educational technique cannot be said to be proved, I think there is no doubt of the computer's relevance to the sciences, at least on their higher levels. In my view, the introduction of computer-based curricula at an early stage in undergraduate science education is not only desirable but necessary.

To provide instructional materials which will incorporate the computer into the warp and woof of the discipline will require a certain amount of literary and taxonomic skill as well as a thorough knowledge of the discipline and also of computers, not to mention some appreciation for the principles of learning which the social sciences may be able to afford us. I most emphatically do not believe that this can be successfully done on the level of undergraduate professional education by anyone who does not have an academic background in his discipline, and it cannot be done by commercial firms setting out to exploit the potential of the market. Nor can it be done by fiat, with NSF simply turning on the tap and inviting all who have a thirst for federal funds to slake it by plunging into computer-oriented education. Although the effort is, by its very nature, multidisciplinary, I doubt the gap can be bridged by the task-force approach; it must be bridged within the intellect of the individual who undertakes to give form to our desire for effective teaching materials which thoroughly assimilate the computer to the educational purpose.

Perhaps it would be possible to combine three different approaches under the aegis of the discipline by having an agency such as one of the various academic commissions which have been sponsored by the NSF—of which the Commission on College Physics is one—sponsor the development of instructional materials which will make use of the computer. This could be done by convening a group of selected professionals to discuss the development of materials in a given area. After developing an outline of what needs to be done and how to go about it, the group would then select individuals to tackle various aspects of the subject at their home institutions, coming together, when necessary, to iron out differences and plan further developments. The group as a whole might be supported by a grant administered through the agency or commission, their product to be a course outline, syllabus, collection of materials, or perhaps an entire textbook, to be prepared by the agency, let us say, in cooperation with a commercial publisher who undertakes to do the job; perhaps similar to the way in which McGraw-Hill undertook to publish the Berkeley series of physics texts (and I would be very interested in hearing the publisher's appraisal of that effort, if possible).

At the Commission on College Physics we have not actually done this, although we have attempted some experimentation in that line, like getting people together, having them produce materials which, although not part of an integrated whole, were nonetheless of the same general character and thrust. Their work was then collected, edited, and published by the Commission on College Physics as a monograph, which was distributed free of charge to all requestors. In this way we have produced two monographs containing short, computer-based teaching units in physics. The first monograph, *Introductory Computer-Based Mechanics: A One Week Sample Course* (55 pp.), consists of an Introduction, Student Manual, and Teacher's Guide, and is a self-contained slice of curriculum, designed to introduce the subject of harmonic oscillation to introductory, noncalculus, physics classes. Students are expected to understand velocity, acceleration, and Newton's second law ($F=ma$); however, no previous exposure to calculus or familiarity with Hooke's law of restoring forces ($F=Kx$) is necessary.

The course week is organized into three lectures: Day One, Day Two, and Day Three, and one Laboratory Session. In Day One, the integration of velocity from acceleration and displacement from velocity are discussed, using simple first-order approximations. Day Two explains and illustrates the translation of the equalities of Day One into assignment statements for use with the computer, and outlines a procedure for integrating the equation of motion of the simple harmonic oscillator. The full computer program for solution of the oscillator problem is presented in Day Three, along with a step-by-step explanation of the program, complete with flow chart and detailed descriptions of the computer language.

Program listings for Day Three are made available in five different languages as requested: BASIC, FORTRAN, APL, JOSS, AND PL/1. Although the Manual and Guide are to be used separately, they are bound together (including four languages) for initial distribution to faculty. Student Manuals may be purchased in quantity at nominal cost, in any desired language variant. Simple as it was, this monograph excited considerable interest and we have sent out about 3,000 copies on request.

The second monograph, *Computer-Based Physics: An Anthology* (203 pp.), is a collection of nine units, each somewhat shorter than the preceding monograph, but constructed on the same pattern of Introduction, Student Manual, and Teacher's Guide; each unit including the complete listing of the programs used, in either BASIC or FORTRAN. About 2,300 copies have gone out in the year since publication. Although I plan to mail a questionnaire to all recipients, I have not yet done so, and I cannot say for certain how they were used or the students' response to them. The only comments I have received were favorable, naturally; I can only point out that about 4,000 Student Manuals for the first monograph have gone out separately on request.

Now there are some drawbacks: Even working full-time as editor on this thing, it took me three months to get out the first volume and it was nine months after that before the second was ready. The time lag seems to be a function of the number of authors more than the number of articles. People do not as yet take the provision of such materials very seriously and do not write as professionally as they would if they were writing a book or a paper for a teaching journal in their discipline, such as the *American Journal of Physics.* Somehow, a note of respect has to be injected into this from the beginning; in a sense, this is at the heart of the problem.

I am trying bravely to do this with the Proceedings of our August conference on Computers in Undergraduate Science Education. Of the 50 speakers, I believe that we will have some 40 usable papers for our Proceedings, and I have already indicated that we expect to be very firm about deadlines and guidelines, and so forth. There is also an editorial staff of five tenured academicians—three physicists, one chemical engineer, and one psychologist—each committed to a thorough job of editing a segment of the conference. One reason for doing this is that it is an attempt to establish some kind of a permanent literature that people can refer to when trying to introduce the computer in scientific education, so that it will not be necessary for every one of them to redo the simple harmonic oscillator. There is also a desire to "legitimize" this approach to the curriculum by producing materials of a substantial and archival nature which can be found on library shelves in the future.

Unless introducing the computers into education becomes a legitimate goal of an academician's creative efforts it will be very difficult to get the best people to do this kind of work. And as a result the task-force approach runs the risk of producing material which is mediocre and short-lived, unless, of course, one can find someone who is outstanding to head up this task force. In that case it may be fruitful. But he will need very broad experience as well as first-class intellect, a deep-seated sympathy with the learning needs of the students, and an understanding of the computer's relevance to their future professional goals.

An additional drawback to the federally financed task force is that when the agency finally does publish something, it is likely to be filed away with the other free and oversized paperbacks; or, worse, it may be buried in the U.S. Government Printing Office catalog, known only to a favored few. If a more permanent or attractive edition is desired, you may find that no publisher is interested in anthologies, as in the case of our conference Proceedings, because federal copyright strictures just do not make it worth their while. So, in our case, we are constrained to produce these Proceedings ourselves, and I have had to go out and find a good scientific copy-editor who knows book production and can consult with me on the selection of a composer, a printer, a binder, a galley-proofer, etc., etc., ad infinitum. Perhaps the answer lies in the publication of a quarterly computer-oriented education journal under the aegis of one or more of the professional societies, supplemented by a biennial conference.

I think that a more satisfactory answer to the production of computer-oriented instructional materials is to interest individual academicians to undertake comprehensive, long-term projects, such as writing texts in the traditional manner, as part of their professional goals within their disciplines and at their home institutions. The sort of materials that I have in mind could be computer-based laboratories on all levels, whole courses, or perhaps a completely restructured undergraduate curriculum fashioned with a view to the total assimilation of computer usage into the discipline. One might also go further, assigning course responsibilities to different disciplines and harmonizing the whole, so that certain fundamental aspects would be taught in mathematics, others in electrical engineering courses, with applications and further developments within the appropriate disciplines, and then testing the products in detail.

The point of this effort is the proposition that by using the computer one can learn things that cannot or will not be taught any other way. In physics, for example, computer usage naturally introduces more precise notions of errors, of algorithm construction, and the value of recursive procedures; it leads to the study of numerical methods and an early appreciation of scaling and similarity arguments; and it can re-create a sense of *discovery* on the part of the individual student as he performs computations on complex systems or simulated experiments.

In writing my own textbook in introductory physics, I have tried to embed a reasonably complete elementary course in numerical analysis and its attendant algorithm construction, using a language-free presentation by means of flow charts. Hopefully, the computer-based material will be assimilated into the text and not stick out like a sore thumb. So, for example, Gaussian reduction and the Gauss-Seidel method are demonstrated in the context of circuit theory; quadrature is discussed in connection with the period of a real physical pendulum; simple linear regression and curve-fitting of data through statistical techniques tie in very nicely with a heuristic derivation of the Maxwellian distribution of velocities in a perfect gas; etc. Since half of the time I did not know what I was going to do in advance, the unfolding interrelationships brought with them a real feeling of discovery and intellectual satisfaction.

However, a book is only as good as its author. And so we return to this question of attracting good people and legitimizing computer-oriented science. Perhaps it will still take another five or ten years before we have a generation of educators who have grown up with computers at their fingertips and just automatically think of computers when certain types of problems come along. It has to be ever-present in the back of your mind if you are to apply it in a natural way.

But once this generation has grown up, how do we get university departments to recognize this area of endeavor as a valid and important one, deserving of respect and accommodation. That is part of the larger issue: What is the position of the scientist as a teacher? Is education to be coequal with research or just, literally, a poor relation? I think this issue is a major contributor to the conflicts which are tearing apart our universities, and which must be resolved in this decade, one way or another. If a student spends four to eight years of his life and anywhere from $2,000 to $20,000 on tuition, what constitutes his "money's worth?" Perhaps graduate education should be relegated to advanced research institutes and not allowed to pollute the virgin springs of undergraduate education. However, if one removes the source how long will the spring continue to flow before it becomes a stagnant pool? So I do not think that is the answer.

I do think that specifically educational posts or chairs should be created on the professorial level as an integral part of departmental activities—a "white revolution," if you will. So the teacher's choice may not always be one of being relatively respected and active in a dull environment or being relegated to second-class status in a good school. A teacher should be able to devote himself to this kind of work without the feeling that he is putting himself at a professional disadvantage. He needs to have a chance to grow and learn more; he should not be given the "dog courses" or an extra-heavy load if he wants to do original work in scientific education. He should not have to find himself an expatriate in the School of Education, when his heart is yearning for the physics building.

I do not know how to change these attitudes. I think that the Commission on College Physics has done a lot to upgrade the prestige of the teaching profession within physics; but it is not enough yet. Next summer, the Commission on College Physics, having perfected American collegiate physics education, will be phased out. Yet, still, I think that some kind of a national commission is needed for every discipline, perhaps not exactly the Commission on College Physics as presently constituted, but some central organization to maintain lines of communication, a continuity of purpose, and a standard of excellence in education.

Another function such "discipline groupings" can perform is to act as an independent reviewing agency, with close ties to the profession, which can criticize and comment on proposals submitted to the federal government agencies with a responsibility for education. I think that we must recognize the important and perhaps dominant role that federal financing will play in promoting the development and evaluation of instructional materials and their implementation. However, to avoid throwing away huge sums of money on projects built around a good sales gimmick rather than a solid and substantial approach to science education, I think that it is necessary to have intimate and continuing contact between the government and the specific bodies within each discipline charged with responsibility for education. And if such bodies do not exist they must be created by the disciplines in cooperation, perhaps, with the government.

In addition to subsidizing groups and individuals, the federal agencies should encourage publication by easing copyright restrictions and establishing suitable rewards and benefits to supply additional motivation, such as the possibility of gainful publication through a commercial house. After all, unlike oil companies, book companies do pay taxes; nor are they subsidized to maintain prices by restricting production. So it follows that they must be performing a valuable public service or they would not be making all that money. Let them make more, as long as they put the desired material before the public as effectively as the profit motive can insure.

The publishers themselves should actively seek out people and try to get them to do this work. Offer them cooperation and even expense accounts to do some computing if they want to tackle these projects. McGraw-Hill, for example, has set up a procedure whereby authors can come forward with proposals for a series of, say, five or six short computer-animated films they wish to make, including complete ancillary textual materials for teaching. If the proposal is approved, the author needs only to produce flow charts and descriptions of the kind of effects he wants. This can then be edited and sent to a facility which produces the films for them. The program is just getting started, and it looks like it may work. The problem is to make it known to potential authors, and to weed out the good ones from the bad ones. And for this you need to know physics. You need to know about teaching. You don't need to know much about film-making, although you must understand computing and what it can do for you, and preferably a little about programming a microfilm recorder, although this is not absolutely necessary. I think this is very promising as a means of getting together expert technicians and expert educators with a built-in review process and turning out many films of high technical and academic quality.

The drawback here is that something which is merely in the public interest and not necessarily profitable may get short shrift. To take up the slack I would recommend the establishment of a Computer Graphics Resource Center to which people could send tapes and have them made into films or stills at nominal cost—let us say, people who know how to compute and have already checked out their programs on an XY-plotter, for example. Such a center might also obtain fellowship funds for summers of work by interested teachers. I would see it as university-based or -affiliated and run by someone who knows computers and also knows his scientific discipline from an academic point of view—someone who can be counted upon to be in sympathy with those people whose needs he wishes to serve. Such a center has been bruited about of late by various people, particularly those from Brooklyn Polytechnic Institute. The various free-lance films could be submitted to a discipline-oriented Film Repository such as the Commission on College Physics has instituted. Here they are reviewed and, if accepted, acquired and made available on request in various formats at nominal costs. Although things of this nature must derive their inspiration from within the disciplines themselves, expert aid should be available to provide professional production and works must be publicized and catalogued in some readily available form which will be made known to the profession, preferably through the medium of a government-sponsored agency or a professional society.

To sum up, I recommend that materials be provided by teachers recruited from the academic disciplines, working individually or in task forces, under the aegis of the appropriate discipline grouping. The federal agencies should provide increased support in the form of funds and close consultation with the discipline groupings *before* initiating large-scale projects. Commercial publication should be encouraged and publishers' rights respected, although corporate greed should be controlled to avoid conflicts with the public interest. The publishers themselves must be prepared to venture some development capital, also. However, the most important factor is an effort on the part of the universities to hire and make welcome at least a certain quota of people who will devote themselves to educational pursuits within their disciplines.

You could say that my recommendations boil down to a plea for more support and rewards, both in status, and in remuneration for science educators, particularly those with computer interests. Given that support, I feel that computer-oriented curricula are historically inevitable and will come, soon or late.

MONOLITHS, MISHMASHES, AND MOTIVATIONS

David Engler
McGraw-Hill Book Company, New York, New York

Since Roger Levien indicated that he wanted provocative papers, I started out by trying to find a model of provocation. The alliteration of my title should make clear to you that I found my inspiration in the speeches of our alliterative Vice President. And while I have no ambitions to become the Spiro T. Agnew of computer-based learning, I did want to fulfill my obligation to be provocative. Of course, that was before I knew that being a greedy corporate type was provocation enough by itself.

I begin with three assumptions about the unspecified future.

First, that the cost of education-oriented computing facilities will be significantly lower than they are today.

Second, that computers will not replace teachers, textbooks, laboratories, and the like, but rather will displace some of these to some extent.

Third, that publishers will still be providing colleges and universities with textbooks and other non-computer-based instructional materials.

There are those among you who have heard me say on other occasions, in discussing publishers and computer-based learning, that most of us wish only that it would go away. It is risky, costly, and complex.

However, it is clear, at least to some of us, that it will not go away. Thus, we grit our teeth and ask ourselves and others what it will be like when it gets here, when it will arrive, and how it will affect what we do.

My speculations are colored by what I consider to be the analogy to and relevant experience of publishing other instructional materials. In other words, I have an axe to hone. I hope I am being provocative when I point out that the same is true of almost everyone else at this conference.

If you were to build a model of the market for instructional materials in the country at any educational level, you would not end up with the model of a monolith. Rather, your model would be a mishmash.

The demand is for a variety of programs, for differences in content, approach, emphasis, style, and so on. Sometimes the differences are fundamental, sometimes superficial, but differences are in demand. The monolithic acceptance of any program is, indeed, rare.

The mishmash model extends beyond programs. It extends to such aspects of education as organization, administration, evaluation, and many others. I do not believe that this model will change fundamentally. If current trends mean anything, they indicate that higher education will be even more of a mishmash in the future than it is today. In my opinion this will apply to computers as it does to everything else.

Thus it seems likely that we will see large, central facilities servicing many terminals on one or more campuses; small, local facilities perhaps servicing a department; commercial time-sharing facilities servicing a class; or all or some of these in different combinations, in different places. Since these facilites will also vary in respect to the kinds of computers, terminals, and storage devices used, specific instructional programs will probably be available in more than one format and more than one language.

But all this concerns only how such instructional materials will be delivered. The question of how they will be provided goes much deeper. It concerns how such programs will be funded, who will develop them, and how they will be disseminated. To put it in more business-like terms, Who will make the capital investment, who will provide the necessary talent and manpower, and who will do the marketing? I hope my speculations on these questions will provoke a few people.

As long as the market for computer-based instructional materials is both small and experimental, the basic investment will be made by government and by foundations. Seed money will be provided until the crop begins to grow. I do not believe that such investment is likely to be sustained once the market for such materials grows large enough to attract significant private investment. Without such subsidies, organizations involved in developing these programs will have to develop self-perpetuating funding systems. In other words, their capital investment will have to produce enough return to finance further development.

Who could do this? Theoretically, anyone with enough initial capital, the necessary talents, and a means of marketing the product.

A nonprofit consortium, a nonprofit development group, or a discipline grouping could accomplish this if they had perpetual funding or if they could turn enough profit to be self-financing. They would have to evolve into competitive, profit-making organizations. And it *will* be a competitive market; the mishmash model demands it. In other words, these nonprofit and professional organizations would have to become publishers or move on to other experimental programs.

Next, let us consider who will develop computer-based learning materials.

Again, I take as my model the present world of publishing. I realize that looking back at how things have been done in the past is no sure way of discovering how they will be done in the future. Marshall McLuhan would accuse me of driving with my eyes on the rear-view mirror. Computer-types would probably say that I do not understand how computers will change the relationships of authors and publishers to the development and dissemination of instructional materials. And they may well be right.

Nevertheless, I think the conventional publishing model is a useful one to examine.

First, consider why authors write books. I omit here the artist, be he novelist, poet, or dramatist, whose work is not germane to this discussion and whose reasons for writing are much too complex for me to understand anyway. Also, I do not mean to imply that some of the people who write textbooks and other instructional materials are not impelled by the same sort of creative urges that bedevil artists. I am simply incompetent to speculate about such murky things.

Some write in order to make a contribution to knowledge. They are scholars and, good, bad, or indifferent, they have something new or original that they want to share with other scholars.

Others write because they want to help students learn. They are teachers who believe they have special talents or unique methods which will make learning easier or somehow richer for students.

Many write simply to avoid perishing in the academic vineyards. They are survival specialists and what they write is only rarely of interest to more than an insignificant number of other people.

There are, of course, other motivations for writing. Some of these cut across categories.

For most intellectuals, the prestige that attaches to having one's words in print is a source of great ego-satisfaction. This prestige is indeed a powerful motor force behind much writing.

Finally, people write in order to make money. This reason is not often openly admitted or widely admired in academic and intellectual circles, but it is nevertheless a common and substantial motivating factor.

Now it turns out that these motivations are unevenly distributed across the academic population and imperfectly correlated with the needs and objectives of people who want to use textbooks.

The task of combining these motivations with the necessary skills, with an organized time frame, into a workable geographic distribution of various individuals and ingredients is one of the contributions made by a publisher. The more diverse the publishing program, the more complex this function is. The notion that one can assemble on a single staff in one location the right combination of motivations, skills, talent, and so on, is not well-supported by the evidence of the past.

Then there is the idea that computer technology will make it possible for any teacher to develop his or her own instructional materials.

Well, consider the analogy of this older instructional technology: the textbook. Its principal input device, the pencil, is an exquisite example of a low-cost, easy-to-use instrument. The textbook can be programmed in the most natural of the natural languages, although one can point to many dubious examples of just how natural it can be. Authors need no special training in the use of either the pencil or the language in order to write textbooks.

Yet the vast majority of teachers do no avail themselves of this simple technology to create their own instructional materials. The fact that they do not is evidence to me that very few people want to write textbooks or other materials and that even fewer are able to do so.

If anything, the development of computer-based learning materials will require more complex skills than textbook writing does. Furthermore, it will require interacting with a team of specialists. Even today, the development of non-computer-based instructional systems is a complicated, multidimensional effort involving many different kinds of specialized talents working on a high level of interdependence. It may be that such an environment will inspire some teachers who were previously averse to working with pencil and paper to rise to new heights of energy and creativity. Or it may be that good authors will be even harder to find in the years ahead.

Then there is the problem of disseminating or marketing the programs. The problem of disseminating unique, experimental programs to a modest number of highly visible potential users is quite different from marketing competitive programs to a large number of diversified and not-so-visible potential buyers. Getting effective information about a program into the hands and—more important—into the minds of a significant portion of those potential buyers is an expensive process requiring specialized skills and talents. Getting the buyer to make a decision often takes additional skill and effort. Being able to satisfy the buyer by delivering the right product at the right time in the right way requires complex logistical systems, competent staff, and convenient space. If you are going to distribute products to customers, you need facilities and people for order processing, order fulfillment, inventory management, shipping, warehousing, and so on. All of this, marketing and fulfillment, often requires even more capital than product development does.

Nonprofit consortia and development groups or professional groups are potentially capable of performing such functions if they have the capital to finance it all. The question is: Will they want to? I doubt it. And if they do, they will, in effect, become commercial publishers. The same will be true of computer manufacturers, computer software companies, time-sharing companies, and others.

Once more, let me return to the mishmash. Eventually, I believe publishers, in the broad sense, will provide most of the capital for the development of computer-based instructional materials; publishers will contract with development groups and various individuals to develop such materials; they may also develop some of these in-house; publishers will market their own programs, as well as programs developed by others.

Panel Discussion III:
HOW WILL INSTRUCTIONAL MATERIALS BE PROVIDED?

Rapporteur: S. M. Barro

The controversies generated by the speakers were reflected—if not resolved—in the ensuing panel and audience discussion. Two main themes could be discerned: first, the continued clash of views over the merits of alternative software suppliers; second, a felt need to extend the boundaries of the discussion to encompass the role of the student (as participant or "customer") and to place the debate over alternative suppliers in a broader framework.

Of the panelists, H. A. Wilson (Harcourt Brace Jovanovich, Inc.) joined most directly in the controversy over prospective supplier organizations. Wilson emphasized the need for the publisher's role in software dissemination or marketing. Other organizations can undertake that function, he maintained, but as soon as they do, they become publishers. Reacting specifically to Seidel's paper, Wilson expressed his preference for the "mishmash" over the "monolithic" model. He characterized publishers today as being heavily committed to new technology and as having the best record in producing widely used course material. Looking to the future, he stressed the diversity that could be provided by profit-making firms—many publishers drawing on many resources, including professors— and suggested that it would be a great error to shift the dissemination role away from the private sector.

The issue flared once more in an interchange between R. Blum (Commission on College Physics) and R. J. Seidel (HumRRO), the latter citing Wilson's remark that "to get huckstering done you get a publisher" in support of his position that the publisher's need for a quick return is inconsistent with production of high-quality material. Blum responded that "the contention that you can't get quality from a commercial publisher is hogwash," citing McGraw-Hill's high-quality physics material as an example. Seidel, for the moment, had the last word, refocusing the question as one of systematic development of instructional technology versus serendipity, and ending up with a quote from a Britisher, "We can not afford the splendid anarchy of CAI in the United States."

William Schneerer, (Case-Western Reserve University), in his remarks as a panelist, dealt with the profit versus nonprofit issue only peripherally, noting the unusual strategy as Case-Western of creating a university-owned, profit-making organization to supply computational services. His main comment concerned the neglect of the student both as consumer of computer-based instruction and as a potential participant in production of instructional material. He especially singled out the undergraduate student as an "untapped resource" in providing material. This emphasis on the role of the student was taken up in the question period by H. C. Lyon (U.S. Office of Education), who urged on the computer-based-instruction developers the need to focus on the student and the need for more student-faculty relationships and cited USOE policies aimed at assuring students a meaningful role in activities sponsored by his agency.

Lawrence Stolurow (Harvard University) began his comments as a panelist with the flat assertion that the wrong issue was being discussed. He averred that it was necessary to focus first on the process to be carried out, and only then on the form of organization. He cited the bad start obtained from Federal funding in developing computer-based instruction because, he claimed, there was excessive attention given to immediate output rather than to "learning how to do it." Turning to some specifics, he identified neglect of two areas: one, the need of students for interactive experience; two, inattention to the role of the author and his funding needs. Turning next to the question of cost, he declared the cost issue in development a "red herring," saying that authorship in general was not cost-effective (i.e., that costs were not recouped). The cost of developing materials, he said, should be considered partly an investment in research and training and should not be charged in total to particular sets of materials. Stolurow contended that there was a role for all types of organizations, including a marketing role for profit-makers. The need, he said, is to define functions in development, then management procedures, not the reverse.

Among the audience questions, other than those already referred to, the one that elicited the most spirited response concerned the parallel between the computer and earlier technologies. What was to be learned? Was there as severe a problem with the computer in going from experiments to the field? Schneerer declared that electronics (not only the computer, but also EVR, etc.) hold the future. Wilson found the high cost of the computer beneficial in preventing a premature bandwagon effect and allowing more orderly development. Stolurow predicted a role for the computer as part of a mix of media but cited its unique usefulness in developing materials and delivering them as a sign of special potential. Seidel stressed the need for development of educational technology as a key factor in assuring that the computer's potential would be realized.

Other questions that brought answers but no interaction concerned the quality of specific computer efforts in physics (Blum said they were elementary and fragmentary and cited dissemination problems) and the potential role of "quick and dirty" along with "highly developed" materials while instructional technology was still being developed (David Engler (McGraw-Hill) said the former had no market acceptability).

Session IV

HOW WILL HIGHER EDUCATION BE AFFECTED BY INSTRUCTIONAL COMPUTER USE?

Roger E. Levien, Chairman

HOW WILL HIGHER EDUCATION BE AFFECTED BY THE USE OF COMPUTERS?

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In this paper I shall discuss three ideas which are related to one another:

1. Higher Education
2. The Effect of the Computer on Higher Education
3. An Educational Effect of the Computer

Before turning to these topics, however, I would like to define two terms which I shall use.

By the system of higher education I mean that set of organized activities that contribute to the education of people who have progressed either in age or in intellectual accomplishment beyond the secondary-school system. I include in that system, for example:

- Two-year colleges
- Four-year colleges
- Universities
- Graduate schools
- Postgraduate schools
- Vocational schools
- Educational or training programs of industrial organizations both for employees and customers
- Educational programs in the military services
- Efforts by individuals to educate themselves

I imagine the reader could suggest other examples of elements in the system of higher education, and, if so, I would include them.

Now it might be appropriate to inquire what education or, in this case, higher education is. In my opinion we don't know the precise answer to that question, but for my purposes I define education to be the total effect on people or society of the system of higher education. This effect may be good or bad. It may change people's attitudes about themselves or the society. It may change the set of manual, verbal, or intellectual skills they possess. It may affect what people know and in all likelihood it has many other effects. I regard higher education to be the sum of these effects.

I believe that we don't know what higher education in this country is. That is to say we don't know all its effects, but we do have some knowledge about it and could get more if we were interested. We know, for example, that some parts of our system alienate people. We know that some parts degrade people. We know that some parts lead people to believe things which are not true.

We also know that some parts of the system seem to do a good job. They provide services that are much in demand by people who claim after their experience to have benefited greatly, and we have a vast amount of fragmentary scientific evidence with respect to learning and some of the effects of education.

While we have much to be proud of, I believe we also have much to be modest about in our system of higher education. We certainly have neither a comprehensive theory which led to its design nor a widely accepted set of criteria by which to evaluate it—or perhaps even very extensive data describing it. We know, or at least strongly suspect, that there are many ways in which our system could be improved, but I think we should recognize that many opinions are relevant to the question of what may or may not constitute improvement.

I may think a particular style of learning is destructive, but others may believe they benefit from it. I may believe that everyone should enjoy learning about computers, but some may not. I think it appropriate not only to be modest about what our systems of higher education may be accomplishing but also about our opinions (especially out of context) as to what may or may not constitute improvement. My modesty, however, will not prevent me for long from making some suggestions for change.

I have been delighted to learn about the efforts reported at this conference aimed at improving higher education. I may not be as optimistic as some advocates about the impact these efforts will have, but I think it important that new talent be focused on the system and I think the computer will help to do this.

I am not concerned that some efforts may turn out to be harmful. I am sure we can all think of parts of the system which are currently riskier than any risks I have heard about here. I am also not concerned that any single effort will so sweep our system that it will reduce the number of options within it. I am concerned, however, that what we are discussing here may not deal with what I regard as a fundamental problem of higher education.

At M.I.T. I work with people on problems of redesigning curricula, teaching methods, and program design, and I believe in general these efforts have a good effect and it is important that these efforts and others like them continue to be made. I believe, however, the fundamental problem of higher education will not be solved inside of what we now think of as colleges and universities. The problems these institutions face have their roots beyond their boundaries and I think therefore we must look outside our present concepts of these institutions for solutions. The fundamental problem of higher education in my opinion lies in its overall design. Universities aim their principal educational efforts at the young and operate in the hope that their educational programs will adequately serve the interests of their students over the remainder of their lives and yet we know they won't.

In an earlier paper at this conference we heard a discussion of technological forecasting. I believe many parts of our current educational programs are subject to technological obsolescence over an interval on the order of seven to ten years. It may well be that our programs should be devised in such a way that this would not be the case, but I believe until we have more encouraging data on the subject we should not operate on the assumption that they are.

Students are aware of the perishability of their education and are investing more and more of their time in the formal system of higher education partly in an attempt to acquire knowledge which they believe they may someday need but which at the time they need it they will be unable to acquire. This is simply hedging against an uncertainty which will later be resolved.

Students know that after graduation one becomes a second-class educational citizen. After graduation few people are able again to pursue high-quality education as a goal. Training, development, and various continuing-education programs frequently referred to as efforts at "retreading" vary in quality but suffer chiefly from low aim.

Perhaps the current example which illustrates this point best is the very serious situation which is developing among highly competent professional people who have pursued careers in the aerospace and defense industries. They currently face a declining market for the particular skills which they have practiced in recent years and which they had every reason to believe would continue to serve them well for years to come. Shifts in national priority, with which I suspect many of them agree, now put them in a position in which some of their skills are no longer needed and with few exceptions no educational opportunities are available to them to help replenish their stock of intellectual capital. This situation, in my opinion, will have a marked and I think detrimental effect on educational decisions undertaken by people entering our systems of higher education over the coming years. They may be led to avoid fields which seem risky from the point of view of social or technological change and the society will be deprived of their talent in these sometimes extremely promising areas. I believe if our system were designed in such a way that it could respond to these kinds of shifts, students could be protected from at least some of these risks in such a way that we could all benefit. It seems to me people should be able to get high-quality education on demand.

Many doctors these days would like to understand economics, social sciences, and systems analysis better than they do on the basis of their medical-school training. It seems to me this is an entirely appropriate set of interests for a man undertaking responsibility for a regional medical program or the management of a large medical center. It also seems to me, however, we would be foolish to sentence every medical-school student to study these subjects at that stage in his career when he is chiefly concerned about personally delivering medical care to people who are ill. Education in these other areas should be available to those who want it and at the time they recognize the need. Engineers whose education took place prior to the existence of computers should have the opportunity to add an understanding of this new technology to their stock of intellectual capital. The same argument can, of course, be repeated in many contexts.

If our system of higher education were open, a great burden would be lifted from our college and university organizations. Faculty and administration would be less concerned about all those things which their students might someday need to know. Students would be relieved of the guilt feelings associated with taking only those courses in which they were interested and perhaps both faculty and students could get out of the long-range educational forecasting business, which we have demonstrated we can't do very well, into the education business at which we may be somewhat better.

Computers may contribute to the development of an open educational system and if they do I think that would be fine. This basic restructuring is so important that I wouldn't want it to wait for this new technology. I think we should develop such a system of higher education with the best resources currently available for the purpose.

To return to my original point, however, I am not concerned about research on education using computers. I am pleased to see even those experiments which I believe will fail, because we may learn from them. I am concerned by the fact that most of the speakers at the conference have accepted much too easily the present structure of higher education. In my opinion such a conception of our task is far too narrow.

I would now like to turn to the second topic having to do with the impact of computer technology on higher education. Unfortunately I am unfamiliar with the literature on a similar question. In the early fifties it was fashionable to call meetings on the question of the effect of computers on management and/or industrial organizations or both. You will also recall forecasts that middle management would be eliminated; that organizations would change from a pyramid to something with a football on top; that none of us would have to work because of automated factories; and other such things.

My impression is that the computer's effect on management and industrial organizations has been good but not very remarkable. As I understand the current literature we are still debating whether the effect of the computer has been to centralize or decentralize decision-making. Recent surveys of the economic effects of computers are encouraging, but as I understand it, we are still searching for the huge economic benefits which were once forecast. The fact that we are still looking for answers to both of these questions makes me think the effects are not large. I believe we would notice an order of magnitude.

I assume the same thing would be true in education for the same reason. Neither system, that is industry or higher education, is passively waiting to be modified by technology—if it were perhaps it would deserve to be. There will be no shortage of active defenders of the status quo and so I predict:

- Rapid technological change in those parts of the system where tasks are boring and repetitive (information-processing) and where the people who do them have little political power; jobs like payroll, accounting, and student records are obviously cases where rapid change is already taking place; language instruction and other repetitive teaching tasks may fall in this same teaching category. I don't predict any big economic effects, just technological change. There may, no doubt, be improvements in performance and also there may be improvements along other dimensions, like individual satisfaction.

- Computer-induced changes which require organizational redesign or redefinition of the role of people with political power, like faculty, will take place very slowly. I predict this partly because of explicit resistance to change but mainly due to the difficulty of making a good case for substituting computer-based technology for what we now offer.
- An even slower rate of change at the so-called decision-making levels. The great promise in this domain still exists both in industry and the university, but there have been few demonstrations of the computer's effectiveness at this level.

There are many good things to be done in higher education and computers will no doubt help, but we have a long way to go to make this potential improvement and promise a reality.

My last point has to do with an observation on the educational effect of computers themselves. In my opinion the principal educational effect of the computer on students I know has been to teach them about programming computers. This may sound cynical, but I don't intend it to be. I think learning about computers may be a significant educational goal and one which may over time help us to understand, far more fundamentally than we do now, an important part of the process of education. Before turning to that more serious question, let me cite the evidence I have to support my suspicion. I have gathered it from talking with students. When I do so, they report enthusiastically on opportunities they have to work with computers. They enjoy working with them and they claim to learn in the process. When I ask what they learn, they don't tell me of the various problems or the techniques they explored which were in most cases the primary purpose of the various courses they studied. They say instead, sometimes in glowing terms, that they have learned to use the computer system and they seem to have great confidence in what they learn and their ability to apply this knowledge in other contexts.

I am aware, of course, that such testimonials are not unknown in education and that they do not constitute proof of the validity of the claim, but I know and respect many of the students who make these observations and I consider their opinions important.

I suspect that in the course of learning how to solve a variety of problems and to use a variety of techniques with the aid of computers, students develop modes of thought which may be quite general and valuable and which we now only very dimly understand.

HOW WILL COMPUTERS COME TO AFFECT COLLEGE-LEVEL INSTRUCTION?

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As a subtitle for my talk, I would use "An Essay on the Virtue of Believing that the Future Is Not Already Here." For it seems that to speak of technology is inevitably to speak of the future—and of the happy times then to which technology will automatically bring us. Our students have been reacting recently to some of the unanticipated, and somewhat unnoticed, side effects of technological advance. We must consider ourselves warned of the hazards which accompany the assumption that the doubling factors referred to yesterday by Dr. Hammer will bear us to a safe, or even comfortable, haven.

The problems of higher education are so immense, and so reflective of the human state, that we must clearly state the premises which underlie the belief that the computer can solve any of them. The computer is an interesting, but weak and imperfect, tool—and rational planning must take full cognizance of its limitations.

Reports in the *New York Times* and the *Wall Street Journal,* to say nothing of the W. S. Bowen study of the prospects for Princeton and certain other universities, [1] make it clear that the current overriding crisis in higher education is fiscal. Our society has developed no adequate way of providing advanced instruction to our young people that is consistent with the expectations and rooted practice of the academic professions. The yearly escalation of the unit cost of higher education has been almost constant for 20-25 years; we in higher education have been able to watch the onset of this crisis without lifting a finger to address it.

The credibility of our colleges and universities is challenged in other ways. Many question the relevance of college courses; these questions lead on to the *real* need for a college education for everyone. Others attack our large and expensive research enterprise—the backbone of graduate study and advanced professional training—as inimical to the best interests of undergraduates. Or, to get away from parochial issues, the evolution of social and political life in this country appears to threaten the university. Some believe that the young are developing a new consciousness, as powerful in its time as the consciousness that previously shaped the industrial development of this country, or the consciousness that gave rise to the emergence of overwhelming Federal influence in the 30's and 40's. Our schools and campuses become, almost by accident, the battleground in our society for a struggle which could become more bitter and more violent before this new consciousness is admitted to positions of power. [2]

It is the resolution of these issues which will shape higher education in the next decade. They will require the fervent application of human genius and love; for the most part they lie well beyond the likely range of technology. Recognizing human frailty, it is hard to be sure that even the more limited questions of the character and quality of instruction can continue to be regarded as critical problems, worthy of the great dedication of effort that is clearly required to change either. But more than anything else, we should not believe that computer technology has more than the aroma of promise in this already limited area. To a certain extent, unfortunately, the implication of the questions addressed by the panels here suggests somewhat more.

Computers may affect instruction in higher education through three different routes:

1. Through academic areas in which the computers and associated techniques are themselves the subject of instruction, such as science, mathematics, engineering, or computing;
2. Through disciplines in which high-speed computation might reasonably alter the emphasis and procedures used in teaching them;
3. Through instruction in which the computer is not involved except as it mediates portions of the instructional procedure.

Much of the discussion that has taken place here has not distinguished sharply among these as different problems. The first and second appear to me vastly different, in terms of instructional development, from the third. I believe that the academic processes which gradually change the content of instruction are adequate to assure that the computer will be amply involved in instruction about, and because of, itself. Professors who are actively engaged in research which uses, say, conversational programming techniques will be sure that their potential assistants, both graduate and undergraduate, become familiar with these techniques as a regular part of their training. Thus, instructional involvement of types one and two will proceed fairly rapidly without careful planning; special outside fiscal support for this purpose is more like cake than bread. Indeed, perhaps the most effective strategy to promote the direct use of computers in instruction would be to forbid the faculty to do it.

My remarks from here on refer solely to the third way in which computers can affect instruction—i.e., as an integral part of the instructional process. From bitter experience gained as we have sought to cause media such as film and TV to support learning, we know that significant involvement of technology in instruction does not occur by accident. Indeed, it hardly seems to occur even under the most generously favorable conditions. This kind of disappointment (not so familiar perhaps to those who come to these considerations out of a computer background) strongly suggests caution in trying to estimate the rate at which fundamental change in instructional processes can occur.

In part, it is just this experience with TV, teaching machines, and other paraphernalia which causes me to assert that, within the next ten years, I do not foresee the computer having a significant transformational effect on the instructional process in higher education. However, with careful planning, with a tremendous amount of dedicated effort, with continued and increased support given to graduate programs in the field of instruction, and to computer science programs, and with the continued inventiveness and energy of the computer industry, it is my best judgment that the end of this coming decade can see the beginning stages of a profound transformation, if higher education is around at all.

To achieve even this much will require such an incredible attention span and directed effort for us professionals that I have chosen to interpret "how" in the question for this afternoon's panel somewhat differently from the way Roger [Levien] may have intended—not to say what higher education will look like when the transformation is made, but rather to lay out over a time span of 10 years the major problems that must be solved, and to sketch in the nature or the efforts needed.

Another premise: For our present purposes, I will assume that junior, senior, and graduate level instruction function relatively well under our current procedures and will only incidentally be affected by the computer as an instructional instrument. This premise is really one of appropriate humility—we know so little about the instructional process that it seems quite unlikely that, for sophisticated learning tasks for which we have reasonably small and adequately staffed classrooms, we can expect to know anything profound about doing better within 10 years.

Although past experience with other technologies in instruction must be considered carefully, we must recognize that the computer has the capability of addressing two major areas of instruction which are available to technology almost for the first time. Film, TV, tapes, and books are largely presentational in character. Good presentation can expedite learning, we believe, but it is only a part of the whole scheme. Student learning is also enhanced by processing his attempts at production. This recognition lies at the heart of the student-teacher interaction in the small classroom. It also accounts for the importance of carefully reviewed homework assignments, of supervised laboratory procedures, and, to a lesser extent, of frequent graded tests. Up until now, the only processor in the system is the teacher. If we are lucky, there are new ways in which computers can process a student's natural language production which are supportive of his efficient learning.

The second major instructional area available to computer support derives from its ability to manipulate data banks: i.e., the administrative area. Our present instructional patterns are hobbled by the necessity to handle large numbers with a negligible administrative apparatus. Many of the most unpleasant features of current elementary college-level instruction, both from a learning-conceptual point of view and from the student-faculty view, are forced by administrative necessity. Hopefully, by efficiently manipulating data about a student's characteristics and progress, the computer can shape the organization of learning tasks for efficient mastery for each person. But—it is exactly the enormous scope of these possibilities that warns us that progress may be slow and hard.

From what I have heard here and elsewhere, hardware and the associated operating systems adequate to realize potential in these two directions will begin to become available in 1975 if we can maintain the present momentum and interest. By adequate I mean reasonably inexpensive terminals with low requirements for maintenance and minimal repertoire of interaction capabilities—for example, the Bitzer terminals. System reliability, organization, and management has to be such that the student gets what he comes for, exactly at the time he comes, 99.9 percent of the time. Toward the end of the decade, then, we should have the capability to run some fairly significant instructional experiments.

But if this estimate seems pessimistic, and remote in time, remember that the hardware may still at that time be years ahead of where we are pedagogically. The current programming languages for instruction are inadequate, but for a very profound reason—namely, that we do not know how to process a student's natural language production in ways that are suited to the computer, and at the same time, are clearly supportive of his efficient learning.

From this, it is quite clear that I am rejecting the familiar tutorial-dialogue interaction as a promising direction of instructional support—indeed, the more we persist at it, the less promising it looks. This kind of dialogue may be appropriate in small classrooms or between two humans, where there are many senses involved in the comprehension of the verbal message; it seems highly inappropriate to the present capabilities of computers. Further than that, we know almost nothing about the pedagogic structure of such dialogues—except that each teacher has his own style, and that *his* style is likely to override any shaping of the dialogue that might derive from the characteristics of the learner in front of him.

Right now it is almost embarrassing to point to instances of natural-language-response processing paradigms that match the processing capability of the computer, and which have instructional significance. The work is in a primitive stage; what we have seems trivial or bizarre or both.

At Stony Brook, we have worked a lot with an unlikely dialogue algorithm. The target for the student is the construction of a specified word, or sentence, or symbol string, in accordance with rules he has been given. His response is compared with the target string, essentially symbol for symbol. If his response is less than perfect, his next response to the same target is cued by displaying to the student those letters or symbols which were correctly chosen and placed, omitting those which were wrong, and displaying dashes for those symbols for which an alternate choice must be made. This algorithm has been used with considerable satisfaction and success in second-language learning. [3] Such a dialogue bears no resemblance to ordinary classroom practice—it is, so to speak, computer-shaped. It is also apparent that it has no believable validity as a stand-alone procedure; the presence of other forms of instruction (syllabus, books, classroom) is implicit, both to provide the rules, and to assure that the students attempt at the target is at least 50 percent correct on the first pass.

Another algorithm we have used is intended to support the student's control of a technical vocabulary. The target for the student is to produce the word, or word group, from as few cues as possible. He determines the mix of additional cues and retries as he goes along. The cues may be ordered in presentation, or randomly selected from the bank, at the instructor's determination. The student, before leaving the item, has the opportunity to see a significant fraction of the cues in the bank, and to ask for the item again if his production did not meet his own standards. For performance below a preset criterion, he must redo the item. Again, students having this form of review support available to them show significantly improved ability to recognize the technical terms.

Neither of these pedagogies bears much relation to a dialogue that would be suitable or acceptable between humans. Hopefully, as they stand, they are not suitable even for a man-machine interaction. They exist; and students find them satisfactory and helpful over an exposure period well beyond mechanical novelty. They give us reason to hope and to work even harder; but progress requires invention and understanding of a difficulty that makes it risky to assert that we will have many such pedagogies by 1975, or even 1984.

The other dazzling prospect for computers foresees the manipulation of data bases. Rapid information retrieval can, in principle, make the whole instructional process responsive to individual students first, rather than to administrators and faculty as at present. Implicit, however, is the existence of a data base suitable for computer storage and massage. In spite of very serious efforts of the past decade, everyday instruction has proven enormously resistant to codification. Many different kinds of proposals have been made for organizing the content objectives of instruction; these schemes have had little general support in the teaching population, particularly at the college level. The disciplinary mastery expected of students has only the thinnest coating of institutional determination; it is overwhelmingly determined by the idiosyncracy of teacher and classroom; recent developments have reduced rather than increased the influence of judgment from a professional group as to what should be mastered, and to what level of proficiency. Another way of saying all this is that the detailed goals of learning are already so completely shaped to what students and faculty perceive as appropriate effort that it is hard to imagine a design which does better.

Implementation of procedures that shape instruction to student characteristics also implies that we know something about what happens to students in conventional current instruction, and why. Again, we know nothing systematic about the relation of courses of different design to the cognitive gain of the students who take them—in the short run or in the long. Adaptation of the methods and the content to the presumed spectrum of abilities and interests of the students in any given group—premeds, or architects, liberal arts, or whatever—is done on a totally intuitive basis. Conventional practice in colleges produces an orally transmitted history, and a local set of attitudes and conventions; most gains from experience are just lost. We hardly know if there are courses which are stable enough to justify the expense of extensive pilot study. Dr. Ernst Rothkopf has argued persuasively for the dedication of effort to the creation of short-term and long-term course memories.[4] Clearly, efforts to use the computer to make course administration more flexible depend critically on our following his suggestion.

How do we get to the future? By surviving the present, first of all. But beyond that, by recognizing that the problems which presently impede progress are fundamental and non-trivial. There must be many wrong starts and complete failures, and through all of those, support must go on. What is done next must depend rationally on what has been done before. Contributions will come from many directions, but the academic research programs in computer science and in instruction appear to me to bear the responsibility for assuring that this research and development gets done. I hope these emerging programs can become sturdy enough to tackle the task.

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COMPUTERS AND THE FUTURE OF EDUCATION

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The turbulence of the American university today has so many causes and needs so many cures that it defies comprehensive assessment.

McGeorge Bundy
DAEDALUS
"Rights and Responsibilities:
The University's Dilemma"

After growing wildly for years, the field of computing now appears to be approaching its infancy.

John R. Pierce
Report of the President's
Science Advisory Committee
1967

We are asked today to speak to the question: How will a revolutionary technology, which has already made major transformations in many facets of American life, affect higher education, which is variously described as being in turbulence, embattled, and in the throes of multiple crises: crises of authority, of fragmented purpose, and of financial support? Let me say at the outset that I can not approach this topic as a technological forecaster or market analyst. Any such approach assumes continuity of the major parameters. But if our society has entered an "age of discontinuity," as Peter Drucker* suggests, no institutions in our society are going through a discontinuity more sharply unpredictable or suggestive of pervasive change than that of our educational institutions. Furthermore, very few inventions of man have been as revolutionary as the high-speed computer in their potential or actual impact on the course of history. Hence, in discussing the effects of the computer on higher education, let us start with a full realization of the discontinuities that lie ahead for both of these technologies—education and the computer.

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* Drucker, Peter F., *The Age of Discontinuity,* Harper & Row, New York, 1961.

Let us begin with the major discontinuities which face education. To put it quite bluntly: Education and educational institutions today are in deep trouble. This central fact of life is finally being acknowledged not only by our students and by the society at large but even by our professors and public-school teachers—those who seem to be the last to have become sensitive to an impending crisis. Although we are processing more students at every age level and are expending more money per student than ever before in history, we are faced with what appear to be insoluble problems.

I am not going to address the problems of our computer centers, most of which are operating at a deficit, nor of our computer science departments. It is a tribute to the vitality of this field that our own Department of Computer Science is growing at the rate of 30 percent per year. This continuing expansion makes computer science unique among our departments in the natural sciences and engineering. Nor am I going to discuss what many people, particularly administrators and politicians, consider to be the number-one problem on our campuses today: student confrontation and violence. Let us agree that it is a necessary condition for survival that our campuses stay open and do not become the battlegrounds for national guerilla warfare. But although necessary, this is not a sufficient condition for our survival as viable institutions. There are substantive *educational* issues which we must face up to—and it is my intention to address some of these problems and to suggest possible avenues to solutions.

Despite the ever-increasing need for more education and greater flexibility, our rigid institutional structures and traditional instructional methods are actually decreasing in effectiveness and productivity. Our decline in effectiveness and resistance to change are the first major issues to which I want to speak today. It is my contention that modern technology, especially technology centered on the high-speed computer, can reverse the decline and significantly increase educational productivity. At the same time, I will try to show that such new technology also provides a tremendous leverage for much-needed change in all facets of our reluctant educational establishment.

At every level of education we have evidence of unmet educational needs. In the elementary grades, a shocking fraction of children leave ghetto elementary schools as functional illiterates. Shocking also is the relatively low level of verbal and mathematical skills and ability to engage in critical thinking which the average learner from our cultural mainstream achieves by the time he graduates from secondary school.

In colleges and universities our students at both the undergraduate and graduate levels are taking issue with the style, structure, and relevance of our educational programs. Not only are students objecting to the lock-step of our typical curricula, but also they are demanding a departure from an educational format which is designed by and intended to train specialists, particularly academic specialists. In all too many cases, these criticisms hit the mark.

In the past, the educational system has responded to an expansion in the demand for education by increasing the size of the overall establishment without changing either the structure of the institutions or the nature of the instructional process. To provide higher quality at colleges and universities, we have used the professor's definition of quality and have concentrated our efforts on graduate education—aimed at the training of specialists in the major disciplinary areas. To provide more quantity, we have replicated our institutions. And the new institutions, far from striking out in new instructional directions or alternative fields of specialization, have typically concentrated on establishing respectability, which is to say they have emulated the established institutions in both the goals and methods of instruction.

We all recognize the key importance, at elementary levels, of individualized attention to pupils of widely varying motivation and preparation. At the college level, students are also demanding individual treatment, with much greater flexibility in establishing both undergraduate and graduate programs. And at all levels, the conventional classroom and sequential curriculum greatly impede the normal process by which anyone learns. In the first place, subject matter is usually broken down into "logical" steps which represent better an adult's way of teaching than a child's way of learning. The class marches through these steps at a set pace, with resulting boredom or bewilderment for one fraction of the class and a general underdevelopment of learning skills for that part of the class whose achievements under this system come to represent a human norm. Secondly, the learner stops being taught not when he has acquired the desired skill or set of concepts but rather at an arbitrary cut-off point in time: the end of the period, the end of the school year, the date of the final exam. In addition, even the most ambitious teacher is forced to address the average student—a being who exists only in the realm of concept—proceed at an average pace, and make assumptions as to an average cultural inheritance. Moreover, the classroom frequently becomes the locale for the public exposure of individual limitations. Far too often, pupils with less preparation are seriously discouraged when thrust into competition with more advanced students in this exposed environment.

Thus it is not clear that the expansion of the establishment has resulted in a proportionate increase in either the quantity or the quality of education. Unfortunately, at a time when we as educators have finally begun to be aware of the need for a new look, society has begun seriously to curtail its support. We are in a financial and political crunch.

Our educational inadequacies as a nation are not limited, moreover, to the clientele of our institutions of formal education. There are also vast unmet needs for education among the two-thirds of our population who are not enrolled in these institutions. Technological change has already rendered many occupations obsolete and is threatening still others with extinction. When large numbers of people feel potentially or actually cut off from the rewards promised by society, the bases of common understanding and constructive social action are eroded. To meet our national needs, we must provide all our citizens not only with training for a specific occupation, but also with new skills which permit a relatively untraumatic transition to jobs demanding different levels of education.

It is a major thesis of this paper that modern computer-based education can and will provide an effective and economically viable mechanism for addressing many unmet educational needs and increasing both the quantity and quality of education at all levels from preschool to continuing education. In addition, this new technology offers a powerful tool for innovation and change in our curricula and in our institutional structure.

As most of you know, I have been professionally involved with the development of the PLATO program in computer-based education, which Professor Don Bitzer has described in an earlier paper at this conference. As you also know, we are persuaded that a PLATO network is a viable concept, with thousands of student consoles served by a single computer center.

We are well along in our efforts to implement the first demonstration PLATO IV system. Even in this initial prototype model we expect the system to be truly cost-effective, especially in higher education. We believe that the economies of large-scale production will bring the costs down to our target cost of well under one dollar per student-contact hour.

A single PLATO IV system with 4,000 consoles could augment by about 20 percent the undergraduate instructional capacity of all the public universities in the State of Illinois. The total number of students involved is over 100,000, and the total educational bill to the State of Illinois of the seven campuses involved is well over 500 million dollars. The cost of a PLATO system for hardware, software, *and* curricular materials would be of the order of one percent of the total. Even with only 500 student consoles—a modest increase over the number on current time-share systems—we could increase our instructional load at the University of Illinois by at least 10 percent, and we have over 24,000 undergraduates.

We have paid special attention to the economics of computer-based education in order to increase the likelihood of its adoption; our target costs are less than the equivalent direct-instructional costs in elementary public schools. However, the major implications of PLATO-like systems in higher education are even more profound and promise more far-reaching changes than those relating to instructional costs. Such systems could have a major impact in alleviating some of the most frustrating features which characterize our educational establishment today.

I see the development of a computer-based education network—not one which ties together a heterogeneous conglomeration of incompatible computers at various college campuses, but a manageable and well-administered network centered on a new technology relating computers, communications, and video and audio displays. Eventually, I think, student consoles will be located in individual homes or offices, with a national configuration of computer centers—a public utility operated in the private sector—serving the individual schools and homes. Three new key features, incorporated in PLATO IV, are essential: compatibility of one institutional user with another, privacy for the individual student, and control by the educator over the curriculum and course offerings of his own institution.

I believe that major changes in higher education will be made possible by a PLATO-like system. Among them are the following:

1. A restructuring of the current lock-step in the time required for courses or degrees together with individualized undergraduate programs for each student will become possible. The typical student could complete his baccalaureate degree in three years or less, some going on into graduate study during their second or third year.

2. Individualized supplementary instruction could convert most classroom work into seminars or individual interactions between students and professors—a

dramatic change in the role of human teachers, emphasizing the development of new ideas, discussion of personal values, and the improvement of understanding.

3. Individualized computer-based instruction will make possible remedial instruction and tutorial assistance for students (and professors) who are not well-prepared. The lock-step sequencing of courses and the "scheduling" of courses will gradually be eliminated. Computer-based education will make it possible for students (and ex-students) to arrange for instruction when their schedules and their moods permit.

4. A computer-based education network will provide unique opportunities for continuing adult education. Student consoles in public schools will be available in the evening at widely separate locations. Resident requirements for graduate degrees will be sharply reduced and a whole new concept of public service for state universities will be possible.

5. Computer-based education will make possible a reformulation of the ambiguous role of graduate teaching assistants, eliminating the economic dependence of large multiversities on low-cost labor and converting TAs to fellowships and research assistantships. Practice teaching would be viewed solely in terms of its value in learning.

6. All students will understand computers and computer languages prior to reaching college age. PLATO currently introduces the concept of programming in the second grade!

7. An educational network will provide a new outreach connecting universities, community colleges, and public schools in other cities and states. This innovation would effect a major change in the physical and intellectual architecture of the university.

8. Computer-based education will encourage major efforts to improve education of nonspecialists and specialists. An evaluation of teaching effectiveness and the learning characteristics of individual students will be continuously available.

In short, I see in truly sophisticated computer-based education not merely a low-cost aid to human teaching but a major lever for effecting change in the entire structure and sequencing of the educational process from preschool to postgraduate years. As to when it will happen, I can only assert the following. If we were permitted the luxury of our traditional business-as-usual, it would take 20, 30, or 40 years. However, we simply will not be allowed that luxury by our governors, our legislators, or our students. The PLATO IV system, the result of over a decade of research, invention, and technological development, should be viewed as a demonstration experiment. A demonstration PLATO IV can be a reality by 1972. If successful, and I am confident that it will be, I foresee a rapid growth in the implementation and use of computer-based education systems, with dozens of systems installed in the mid-70's. A network with only one PLATO system in each state would represent a very small fraction of our total annual costs but could increase the direct instructional capacity available to our colleges and universities by as much as 20 percent —and, as a by-product, increase our available computational capacity by at least 50 percent. I do not believe that our institutional bureaucracy has enough inertia to resist that payoff if the new technology can be successfully demonstrated in a few key areas.

My second major thesis concerns the role of the computer in the formulation and selective acquisition of information and knowledge. Too many educators imply or take for granted that the basic storehouse is the library as we know it; they assume that all information and human knowledge will be stored in printed form and that the crux of the problem in acquiring such information is rapid access to a selected page of text. Now I recognize the central role that the library has played and I believe that computers will automate some parts of it. However, the development of large computers and of effective communications between computers and man holds forth the possibility of a revolution in information storage, acquisition, and presentation which is far more important than, and different in character from, faster access to the printed page.

Some have proposed that everyone some day have access to the Library of Congress at his student console. However, access by each man, woman, and child to everything that has ever been written is not necessarily a key to understanding or a solution to our current problems. It is true that the printed page made the Renaissance man possible. But today the proliferation of articles and books may have reached the point of diminishing returns. Dr. Spinrad emphasized yesterday that paper and the printed page cannot continue as the medium for business transactions. That is also true for education. Our exploding library shelves are intensifying rather than diminishing the fragmentation of knowledge. We have reached a point in the proliferation of publication at which only the expert can follow the most recent developments in his discipline. And there are few incentives for translating specialized knowledge for the nonspecialist. The fragmentation of the academic community, one of the critical problems facing us today, is closely related to the fragmentation of knowledge.

In my view, the great contribution of the computer in this area will not be the automation of the library or the control of the Xerox machine. Beyond that role, the computer offers great promise in the reformulation of knowledge by means of model-building, simulation, and the development of new methods of synthesizing and presenting ideas. Through the use of graphic displays, the results of complex calculations may be presented without a need on the part of the student for all of the mathematical skills or unique vocabulary of the specialist. Dr. William Miller has referred to such computer programs as "the living library." One of the most encouraging aspects of our work with the PLATO III system at the University of Illinois is the tremendous instructional advantage made possible by the presentation of knowledge through computer simulation of complex systems or through the organization of data into an analytical framework that permits an integrated view of a system. In this way, we can provide students with access to such knowledge long before they have acquired all of the methodologies traditionally considered essential for contact with a sophisticated subject.

The transfer of expert knowledge into the common understanding, i.e., the instruction of students who do not propose to become specialists in the particular field, is one of the critical problems of our universities and our society. The power of the computer to reconfigure existing information and knowledge into a form which is compatible with the data-acquisition rates of human beings represents one of the few really hopeful signs that this issue can be addressed successfully in the future.

Since our total annual bill for libraries is only a few percent of the cost of education as a whole, it is highly likely that the expensive development of a new technology for libraries will follow rather than precede the development of an educational network. It is my judgment, however, that when a computer-based educational network is available it will provide the framework for incorporating a "conversational" mode in which the student consoles provide direct access both to library materials and to a new source—the "living library."

A third major issue facing education today is the issue of relevance. While many of my academic friends discard relevance as a valid issue on the grounds that most of the great revolutions in human understanding were stimulated by disinterested scholarly speculation and research, the society of which we are a part will simply not accept this activity as the sole intellectual purpose of an institution of higher education. Even Albert Einstein, perhaps the outstanding example of the disinterested scholar, made clear his own view as follows:

> The concern for man and his destiny must always be the chief interest of all technical effort. Never forget it among your diagrams and questions.

And even if the public which supports our institutions were to allow us to ignore the current problems posed by society, our students have made it very clear that they will not permit us that luxury.

How does the computer fit into the issue of the relevance in education? If there is one quality that characterizes the problems facing man today, that quality is "complexity." Whether the problem involves technological assessment, the examination of ecological balance, management and control of the environment, or the need for social invention, the current problems facing us as a nation completely defy the simplistic approach. If there is merit to the persistent student demand for relevance in education, it lies in the search on the part of many students for a viable role which they might play in dealing with such problems. And they are not satisfied solely with the role of technical expert or social critic. Computer science and technology can help us deal with complexity by placing powerful new means of understanding at our disposal, and by converting specialized learning to the pool of common knowledge.

The entire pattern of graduate education and scholarly research in American universities is organizationally based on the efforts of the individual professor, sometimes in collaboration with one or more graduate students. But the most urgent as well as the most challenging problems facing mankind today, those posed by the political and technological activities of man, cannot be dealt with by a lone professor or graduate student. I submit that most of our traditional disciplines have prepared experts to deal with small pieces of the problems, but not with the problems as a whole.

The development of large, high-speed computers represents the most hopeful support for the human intellect in understanding or coping with complex problems. Not only does the computer permit us to deal with far more variables and equations that a single mind is able to contend with analytically, but it provides a framework for cooperation and a common language for people from different areas of specialization. Above all it provides a mechanism for the education of interdisciplinary people. Despite all of the lip service paid to the need, our academic institutions have been singularly deficient in the development of truly interdisciplinary activities. They have been few and far between. On the basis of my own personal experience, the following generalization is valid: Show me a truly interdisciplinary effort in a university and I'll show you an interdisciplinary person; nine times out of ten, I'll also show you a computer that establishes the approach to a solution and a mechanism for relating the efforts of various specialists.

The advent of the high-speed computer is of special importance, not only to highly sophisticated modern technology, but even more critically to research on social problems, environmental design, and the myriad of man-made problems associated with political and governmental institutions. Although contributions to the physical sciences and engineering raised the computer to its current position of importance on the campus, the use of computers to solve other complex problems posed by society will greatly increase that importance in the next decade.

Let me give one example close to home of a computer-based approach to major problems in the behavioral sciences. The PLATO IV system will represent a major contribution through the direct provision of instruction; however, in addition to that role, PLATO will represent a uniquely powerful tool for research on both the teaching and the learning processes. When I am asked whether we have made an evaluation of the effectiveness of computer-based education, I respond that *we do not as yet have an accepted measure for the evaluation of conventional education.* We do not have a model of the learning process and in the absence of a plausible model it is not possible to interpret our limited measurements. To develop valid educational models would fully justify the investment in a PLATO-sized computer-based system, solely for its research use in learning theory and educational psychology. The ability to collect and process data from thousands of students simultaneously will make possible a new dimension and a new era in educational research. A similar case can be made for the application of computers to many other areas of social science and social technology. We have ample evidence that research and education in these areas are considered relevant by students at all levels as well as by our society at large.

Thus it is my third major thesis that the computer has become a critical element in the acquisition of knowledge and know-how regarding those problems that will determine the fate of our civilization in the decades to come. In this way, the computer will help to provide a viable public-service role for our major universities, a role we have been called upon to reformulate for at least 25 years.

I have previously suggested that the management of a national computer-based educational network is of such complexity and magnitude that the computers, communications, and publishing should be operated in the private sector with control of the educational process in the hands of educational institutions. How about the implementation and administration of major computer centers oriented to other problems posed by society? Such centers, each devoted to a special class of problems, should be considered national rather than local institutional resources. An example is the computer center operated at the National Center for Atmospheric Research at Boulder. I leave it an open question whether universities should attempt to incorporate such centers within their own institutional framework. My own inclination is to envisage a group of jointly sponsored not-for-profit corporations, probably linked with centers of learning via a communications network but operated as independent corporations for the community as a whole.

In summary, I have addressed three critical issues facing education today. First is the need for a whole new approach to increasing educational productivity and to amplifying the efforts of our most gifted teachers and authors. Second is the need to counteract the fragmentation of knowledge and the fragmentation of the academic community. And third is the need for powerful new approaches to the solution of problems of society. In each of these areas computers can tremendously amplify man's ability to process and display data, to formulate and disseminate knowledge, and to provide new and effective methods for dealing with complex problems.

During much of the past decade the number of computers and the investment in computers in colleges and universities grew at a phenomenal rate of 25 to 30 percent per year. We now spend about a quarter of a billion dollars annually for computers in colleges and universities. About half of this we expend in the business office for institutional bookkeeping and management purposes; incidentally, this half of the budgetary expense is seldom questioned by trustees or legislators. It is the other half, devoted to education and research, that is currently under severe financial stringencies. The educational computer center at virtually every campus is operating at a deficit. One of the reasons is historical; the computer was initially supported through research grants and contracts from the federal government. In the face of recent cutbacks in federal support, it is a tribute to the tremendous importance of computers that the growth during the last few years has been accomplished mainly through institutional support.

However, many current applications of computers on our campuses merely enlarge the earliest use of computers as computational aids. As I have tried to indicate, we can now envisage new roles for computers and computer-based systems which hold tremendous promise for education and for society.

Unless we recognize the national stake in the tremendous potential of the computer for education, that potential will not be realized. To do so will call for R&D aimed at new hardware and software, research on new applications, demonstration experiments and operational implementation. These will call for different contributions from the federal government, local and state government, industry, and educational institutions, depending on the objectives and risks. Partly because federal support has been so limited recently, there are too few programs involving major new technological developments or applications of computers to the problems of education or society. The need for R&D dealing with widespread national problems is critical and I urge a major reconsideration of this area by the Department of Health, Education, and Welfare, the National Science Foundation, and other federal agencies. The payoff of R&D in these areas could bring tremendous benefits not only in education but in such other major societal functions as the delivery of public-health service, housing and transportation, and management and control of the polluted environment.

A failure to bring all of our resources to bear on the substantive problems of education will leave our institutions where they are today: on the brink of sharp and catastrophic discontinuity.

In closing, I would like to read a quotation by a keen observer of today's campus scene of student unrest, and I hasten to add, one who is not a technologist. The author is Kenneth Keniston, the well-known Yale psychologist, and the article is entitled "Harvard on My Mind" *(New York Review of Books,* September 24, 1970):

> The opposition of the young provides no "solutions" to the problems it pinpoints; campus unrest is the antithesis, not the "answer" to the issues that inspire it. But if there are ever to be solutions and answers, they must

bring together the technological wizardry and productivity of industrialized societies with the oppositional mentality of youth. That synthesis might really lessen campus unrest, even at Harvard.

I see the synthesis of technological advance with the strident idealism of this generation of students as the only real hope for the survival of our educational system.

THE EFFECT OF COMPUTERS ON HIGHER EDUCATION

Robert D. Tschirgi
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The U.S. society is entering the postindustrial era in which technologically sophisticated service industries will employ the majority of the labor force. Education and health care will be the largest employers in the foreseeable future. Education is thus doubly significant for the economic development of the country in the coming decades: first as the *sine qua non* for gainful employment in a "knowledge society" where all jobs require technical competence at ever-increasing levels of sophistication, and second, as a major employer within the national economy.

The entire U.S educational system, primary and secondary as well as higher, requires major revisions in organization, methodology, and curricular content. The goal should be maximum opportunity for all citizens to receive optimally relevant education adapted to the talents and needs of each individual. There is much evidence to indicate that these objectives can be approached in an economically feasible way through the creative application of modern technology based on the psychology and physiology of learning.*

No major technological impact on education has occured since the advent of mechanical printing and the development of the relatively low-cost duplication and distribution of books. Today's schoolrooms, including most found in institutions of higher education (with the exception of science laboratories), are barely distinguishable from those of a century ago. The professor as lecturer assisted by chalk and a blackboard is still the primary *modus operandi* of the college curriculum and represents a pre-science-age anachronism.

Introduction of individual items of technological hardware, such as projectors, audio and video tape recorders, and even computers as isolated elements, will not accomplish significant and far-reaching changes in education. It is essential to develop a total integrated system of technological devices with the necessary "software" (programs, visuals, lectures, etc.). It is increasingly evident that such educational systems will depend primarily on computers for their coordinated effectiveness—as executive agents for operation of the system; as assistants to the learner or the teacher in the performance of steps in the teaching-learning process; in the clerical functions of recording, testing, and prescription; and as surrogate instructors. To develop such sophisticated systems of educational technology requires:

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*Commission on Instructional technology, printed for the Committee on Education and Labor, House of Representatives, U.S. Government Printing Office, Washington, D.C., 1970.

- Research in learning theory
- Re-education of teachers
- Educational systems experts (in addition to hardware technicians and educationists)
- Social, professional, and economic rewards to faculty for developing and introducing new educational techniques and programs
- Major financial support from government
- Close cooperation between industry, universities, and government in research, development, and application

The eventual impact of computers on education will be enormous, both through their influence on society and thus the curriculum, and as educational and managerial tools. Andrew R. Molnar* has estimated that, by the end of this decade, computers and computer-related activities will account for one-third of our gross national product. Thus, most work activities in U.S. society will involve interacting with computers, and computers will "advise and consent" or control most industrial processes, middle mangerial operations, governmental functions, economic flow, service and professional occupations, complex societal interactions from airline-ticketing to traffic control, and such private household functions as menu-planning, food preparation, budgeting, shopping, etc. Computers will play significant roles in musical performance and composition as well as other fine arts. No area of education will be current without including cybernetics (the communication between man and machine) in its curriculum. The intelligent use of computers will be as much an essential skill for the survivors of the twentieth century as the operation of a dial telephone was to their ante-computerized, and often anti-computerized, forebears.

In addition to their pervasive role in all other aspects of society, computer-based instructional systems are the only possible means of fulfilling the growing aspirations for mass higher education which is simultaneously adaptable to the individual learner, presented most effectively for his learning ability, and providing him with those skills and information needed to achieve his performance goals.

The conclusion that appears most likely on the basis of current evidence is that a fully coordinated and integrated educational system utilizing all presently available technologies for information-handling, and digital computers as the primary executive mechanism can effectively meet the crisis of numbers and quality in higher education. However, to meet the criterion of cost effectiveness, such a system must be developed on a large regional or preferably national base and utilize the national manpower pool of academic expertise for the necessary research in learning theory and the development of curricula and programs.

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*Molnar, Andrew R., "Higher Education and the Post-Industrial Society," paper based on comments delivered at the conference "Computers in Undergraduate Science Education" sponsored by the Commission on College Physics and the Illinois Institute of Technology, Chicago, Illinois, August 21, 1970.

To evolve such educational network systems will require massive commitment of funds and other resources on a national, regional, and local level. A design for a federal mechanism to initiate activities leading toward these goals has been proposed in a recent report by the Commission on Instructional Technology (see above). Through the establishment of the National Institutes of Education in HEW, coordinated programs would be undertaken by government, industry, and the universities to engage in research, development, and application of technology to the educational process, and to create the instructional materials to be used by these technological systems.

The effects of these computer-based educational systems on higher education, should they come to pass, would be staggering. Most institutions of higher education, as geographically defined accumulations of buildings having a limited temporal role during a few "student" years of life; would cease to exist. These technological systems will eventually change the entire fabric of the educational enterprise, and today's institutions should begin the orderly planning of facilities and organizations to accommodate these changes, which will eventually include:

Geographic dispersal of the campus. Through communications technology, the concept of moving the learner to the source of information can be replaced by the widespread distribution of information over two-way interactive networks. The geographic center would be primarily a focus—a "node"—in a technological communications net, housing equipment (computers, transmitters, archival materials for remote access, etc.), support personnel, administration, centers and laboratories for research and scholarly activities, and teachers much of whose student contact would take place via electronic communications media. Terminals providing learner access to the educational system could be placed at convenient locations throughout the community, and eventually in private homes. It is probable that most of the baccalaureate educational program could be accomplished without assembling students as a group or requiring physical presence "on campus."

It is not yet clear to what extent effective learning can be accomplished entirely in the absence of structured live interaction between the educational participants. This can only be determined by intensive and extensive studies concerning the learning process. These studies should be given highest priority in the national concern for quality and mass education and should be conducted *pari passu* with the introduction of various automated educational systems, based upon our present limited knowledge and experience.

Redefinition of "student" to include any individual within the area who can demonstrate prerequisite performance qualifications for the educational program of his choice. The goal of the institutions of higher education should be to extend their services through technological communications media to any subscriber within their domain, irrespective of age, past educational continuity, etc. Assuming that economic feasibility has been provided, the only measure of a student's admissibility to a particular program should be based on the probability of his competence to master the material as demonstrated by his past performance and/or by placement examinations.

The distinction between "Extension," "Part-time," "Adult Education," "Refresher Courses," and the so-called "regular campus students" would be erased. Any individual, at any time, could accumulate, at his own pace, educational credits through his interaction with the educational network. These records of his progress would be automatically maintained in the central administrative computer, both as the results of his progression through programs and/or as the results of examinations. When a predetermined amount of satisfactory educational accomplishment had been reached, the individual would become eligible for certification by the institution attesting to his academic achievement.

Educational programs available on this basis over the network could range from remedial English to latest developments in medicine and other professions.

The "undergraduate student body" as a societal unit would largely cease to exist. Since continuous learning would become essential for a successful career at any age, the mere process of learning would no longer provide a unique group identity. Nor would geographic propinquity act as it does now to develop a student social structure, since students would be scattered throughout the community pursuing individualized curricular programs.

Greater interdependence among educational institutions and reassessment of institutional goals. The successful and economically feasible operation of an educational communications network requires regional and national cooperation and integration of the facilities, resources, and expertise among institutions of higher education. The proposal by EDUCOM for a national educational communications network* could well serve as a basis for designing regional associations of universities and colleges. The "nationalist" tradition of institutional competition for the biggest library, largest number of Nobel laureates, and most extensive collection of Dravidian potsherds must be replaced by a share-the-wealth policy.

Despite their vigorous espousal of progress, experimentation, and educational leadership, American universities on the whole have shown a reluctance little short of immobility toward exploring newer technological methods of education. If any significant changes are to be realized leading to more efficient and effective higher education through technology, the universities must rearrange their priorities, reorganize their budgets, reeducate their faculty and administrators, and redeploy their creative resources.

Redefinition of "professor" to emphasize his educational role as creator of self-sufficient learning programs, dialectic tutor, academic counselor, and evaluator, rather than primarily a source of expert information. This changed role for the instructional staff in higher educational institutions will require considerable re-education for the faculty. Most do not now know how to utilize the instructional and communications media effectively; most do not now know how to analyze their teaching objectives critically, nor formulate their subject lucidly enough to prepare programmed self-learning materials; most do not know the rudiments of learning theory and the psychology of learning that could be applied to the educational process even today; most are not aware of the considerable body of well-established principles for designing and evaluating instructional programs and tests; most do not analytically comprehend and consequently cannot explicate the mental processes involved in critical unvalued analysis, induction, deduction, problem-solving, and other primary intellectual skills; most are relatively inept in small-group tutorial situations involving elementary levels of the curriculum.

University faculties should recognize that much of the educational process is amenable to rational analysis. For many educational needs—even in the rarified

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*Brown, G. W., J. G. Miller, and T. A. Keenan, *EDUNET: Report of the Summer Study on Information Networks,* John Wiley & Sons, Inc., New York, 1967.

stratosphere of graduate education—some goals can be defined, programs designed for effectiveness and efficiency, and performance criteria evaluated. In general, university faculty have received little or no education in education and continue to perform this function in ritualistic mimicry of their teachers before them. Until they are willing to accept the proposal that the instructional process is not entirely a mystic art dependent upon the interpersonal transfer of an unmeasurable effluvium which cannot survive transmission through electronic media, technological methods in higher education haven't got a chance.

Universities and the organized academic societies must reinstate research and performance in education as worthy and noble activities for the faculty to pursue. Social, economic, and professional rewards should be provided for creative contributions to education in equal measure to those provided for other scholarly and scientific research. Only through this faculty involvement can computers be taught to teach.

Closer cooperation with the nonacademic community and greater responsiveness to changing educational relevance. The great majority of jobs in the near future will require some degree of intellectual skill. Furthermore, the rate of change of technology will require periodic re-education, especially in the technologically sophisticated professions such as engineering and medicine, to avoid intellectual obsolescence. Educational institutions must work with industry to provide the necessary training and skills for the marketplace, and must be responsive to feedback from such relevant agencies as professional organizations, governmental bodies, and society generally in adapting educational programs to the needs of the community. Application of communications technology to the wide distribution of educational services will promote this confrontation between the educational supplier and the customer.

EPILOGUE

The primary goal of mass higher education, as seen by the general public who want it, is job-oriented technical training to enable the individual to achieve a relatively high standard of living in the society where he finds himself. This training process is classified as higher education because it extends one or more years beyond the present format of primary and secondary education. It is necessary because the U.S. society has become so technologically sophisticated that individual economic sufficiency can be achieved only in jobs requiring some amount of intellectual preparation.

This is not an altogether new problem for the United States. By the mid-nineteenth century, large numbers of the population were attempting to establish family farming enterprises along the frontiers and were failing because they did not know the rudiments of farming or how to survive in a frontier situation. The land-grant legislation under the Lincoln administation was created to fill this very practical educational need; to provide institutions through which would-be farmers could be taught how to farm and their wives how to keep the family clothed and fed. The result was one of the great success stories in education, and largely through these institutions, American agriculture became the most effective and efficient in the world.

There is nothing shameful about teaching a man—or a woman—to do a job through which he can attain economic independence and contribute to the social weal. There is nothing demeaning about analyzing the performance requirements of a job, or in developing educational programs and tests to equip individuals to do that job. There is nothing inhuman about watching a TV or motion-picture screen, or interacting with a computer, any more than there is in reading a book to obtain the proficiency required to make a living.

If the children of today are going to inherit a world in which they must have a certain level of technical competence to survive, then it is the responsibility of us, the architects of that world, to provide the means for them to receive the necessary technical training. If this can be done most efficiently and effectively by an automated, computer-based educational network, then such a network should be built.

If the computer-based educational system cannot instill an emotional orgasm in every student on hearing Wagnerian opera or reading Swinburne, it does not follow that the system is a dehumanizing Golem converting its hapless pupils into mechanical robots. Only an infinitesimal number of human beings have ever experienced Wagner or Swinburne, and of those who have, a very much smaller number would care to repeat the experience. It is a presumption of intellectuals that everyone should be subjected to their standards of culture.

If the computer-based educational system cannot unfold the flower of creative genius in us all, it is probably because most of us do not possess that fragile bud. Knowing as little about creativity as we do, it is unlikely that a computer tutor would do any worse than our present educational system.

If the computer-based educational system cannot provide unrestricted freedom of choice for its users, it will be contributing to a healthier society. It is a well-known principle of psychology that an individual faced with too much freedom of action—too many allowable alternatives—becomes anxious, frustrated, depressed, and frequently hostile. His behavior tends to become erratic and unproductive as he vascillates from pillar to post, or withdrawn as he rejects the whole anxiety-producing situation.

If the computer-based educational system tends to present a common set of values reflecting the previous generation of programmers, it will be an instrument of necessary social stability. No society can endure without a certain consensus of values and goals extending both over its geographic extent and through its generations. It is the responsibility of each generation to decide what to teach the next generation. The infant is in no position to debate with his parents what language he shall learn.

What the general public wants to get out of higher education is primarily raised economic status. What university faculties want to give in higher education is cultural refinement, intellectual sophistication, creative impetus, and universal horizons. These ultimately important intellectual attributes, essential for the transmission and extension of mankind's most noble accomplishments, can be taught and learned by only a small number of uniquely talented and motivated individuals. Groves of academe should be maintained to which these relatively few who want or can benefit from such educational principles can repair. For the majority, the relevance of education is measured in far more practical terms and most educational programs can be designed around rather specific performance goals, amenable to the capacities of present-day information-handling technology.

No academician can resist the one-upmanship challenge of who can close with the most illustrious quotation. The gauntlet was cast down with a quote from Norbert Weiner yesterday and routed with Machiavelli this morning. I will now enter the lists with Socrates.

The use of inscribed language on paper, clay, or stone as a "visual aid" to supplement the previous oral tradition of education was opposed by some of our ancestors as vehemently as some academicians today oppose teaching by television or computer. Socrates writes:

> For this invention (writing) of yours will produce forgetfulness in the minds of those who learn it, by causing them to neglect their memory, inasmuch as, from their confidence in writing, they will recollect from the external aid foreign symbols, and not by the internal use of their own faculties. . .*

Later in this same work he objects to the written word on other grounds:

> And so it is with written discourses. You could fancy they speak as though they were possessed of sense, but if you wish to understand something they say and question them about it, you find them repeating but one and the self same story.**

These same arguments based upon the same reasoning are heard today in answer to the proposed uses of computers and associated audio-visual teaching technologies.

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*Plato, *Phaedrus*, trans. J. Wright, London: Macmillan, 1921, p. 104.
**Ibid., p. 106.

Panel Discussion IV:
HOW WILL HIGHER EDUCATION BE AFFECTED?

Rapporteur: G. A. Comstock

John Caffrey, American Council on Education

John Caffrey focused on the relevance of computers to the problem of educating larger and larger numbers. He said he was not worried about technological advances, but about education's "delivery problem." He said that education had lost much of the public faith and understanding it had 20 years ago, and that this was indicated by reduced financial support. He pointed out that meeting the rising demand for higher education was the principal problem, and that we will soon be asked to educate everybody. Enrollment of the college-age group is expected to go from the present 45 percent to 75 percent by the end of the century—"barring other major catastrophes." He agreed with Daniel Alpert (University of Illinois) that expansion is not the answer to avoiding a clash between rising demands and public refusal to provide more of the same "piled higher and deeper." He said that the great value of CAI and related problems was the exposure of how little is known about learning; however, he was skeptical that the calls for greater faculty understanding of learning would lead to much. He observed that if faculty realized that "one of their most cherished objectives"—the elimination of students—could be achieved through CAI, they would support it heartily, and added that this could be achieved at least for dull and monotonous courses.

Henry Chauncey, Interuniversity Communication Council, Inc., (EDUCOM)

Henry Chauncey pointed out that there had been little attention to what would, rather than what should, happen. He acknowledged the riskiness of predictions, recalling Mark Twain's alleged reply to an impecunious inventor, "No, Mr. Bell, I don't think the telephone has any future." He said his own answer to how the computer would affect higher education was, "Slowly—because of the conservatism of the faculty, because of the pride in the course that they teach, because of the difficulty of incorporating a new element." However, he said progress could be speeded up by social invention—an "end run" outside the established system of education to serve the 50 million or so taking correspondence, television, extension, and other kinds of classes. With this group, many of the deterrents to progress would be avoided. He said that two problems would have to be solved: (1) the giving of exams for credit, and (2) the granting of a degree. He noted that there were many models for the former and that the latter had been talked about for some time. He suggested that a new national university, or "open university," might be the means. The resulting program would employ all media and types of instruction, and the computer would clearly have a place.

Raymond Stith, The Junior College District of St. Louis

Raymond Stith noted that the situation was not at all the same for all levels of higher education. In particular, he argued that the teaching versus research conflict that applied to the universities is irrelevant for the 2-year community colleges, where teaching is the prime faculty duty. He said that faculty conservatism could be partly overcome by time allowances and incentives. He pointed out that the computer was already used extensively at the community college level for data-processing education, and that without student acceptance faculty would be hesitant to try any innovation. He also added that there were affective as well as cognitive and behavioral objectives, which may affect how well the computer can be used.

SECTION TWO

Session V
POLICY RECOMMENDATIONS

COMPUTER LEARNING UNDER EVALUATION (PROJECT CLUE)* AND AN ATTEMPT AT HYPERSPEECH

Karl L. Zinn
University of Michigan, Ann Arbor, Michigan

I have known Ted Nelson for a long time and worked with him in program activities of the ACM Special Interest Group on Computer Uses in Education [see the February and October 1970 issues of the *Bulletin* of that group for two interesting reports]. However, only on the occasion of his talk last evening did it occur to me that his work on hypertext has identified one of the difficulties I encounter when presenting a speech or lecture. For example, last week I carefully prepared a detailed presentation on the goals, procedures, and findings of Project CLUE. Although my text already was too long, this week I tied in a large number of other ideas and proposals that occurred to me during the last two days of sessions. What I have now is at least three speeches with many contrasts and interconnections. I try to keep in mind alternate versions of any speech I might be giving, drawing on one and then another as reaction from the audience may indicate. This is certain to fail, since it is not possible to respond to a sufficient number of the listeners with what it is they are looking for. Any one moment there exist too many diverging interests in any group of interesting individuals.

Recognizing that it is not possible to present even a small selection of the interesting material in sufficient detail, I hope to provide at least a set of labels, concepts, issues, and references for further examination by individual listeners. I will try to present a trace or map for finding one's way through a written collection of concerns and tentative recommendations by indicating a number of pointers to paths that might be followed at another time. [Many of these pointers appear in this transcript within brackets.] In other words, I am trying to present a hyperspeech, but without the facility to respond to individuals. [The implications of social hyperfilm, in a very simplistic representation, were explored at EXPO 67 through various schemes for audience determination of the plot continuation presented via a multitrack film.]

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* *An Evaluative Review of Computers in Instruction* is a critical survey of the technology, applications, costs, effectiveness, and trends. It is now in process at the Center for Research on Learning and Teaching, University of Michigan, with financial support from the U.S. Office of Education [grant No. OEC-5-9-320509-0032]. Summary reports appear in the *Conference Edition of the Papers of the World Conference on Computer Education,* IFIP, Box 6400, Amsterdam, The Netherlands, and the *Proceedings of the Conference on Computers in Undergraduate Science Teaching,* Commission on College Physics, 4321 Hartwick Road, College Park, Maryland, 20740.

The impracticality of hyperspeech combined with the predominance of unmodulated hypertalk at this meeting, that is, talking in many dimensions at once without listener control or even interpretation, suggests to me the bringing together of two problems for a mutual solution. On the first day we had difficulty with feedback in the audio systems; a technological resource getting out of control was restricting communication on an inappropriate basis: the handling of microphones when in the vicinity of audio-system speakers. On the second day there was some confusion about the domain of computer uses in instruction and particularly the initials "CAI." [At a recent conference for which I was designated recorder, I told the participants that I would not write down "CAI" (Computer-Assisted Instruction) in my summary unless the speaker explained what he meant by it. I have written about this problem of names many times; for example, in the *Guide to Sources of Information about Instructional Use of Computers* available from ERIC at Stanford, Cypress Hall, Stanford, California 94305. The interested reader might also request my notes on how to get more out of a working conference than participants are willing to put in. The results of one such Unesco session were reported in the April 1970 issue of the SIGCUE *Bulletin,* and another (organized by OECD) I hope will show a draft of its product in the December or February issue.]

Now on the third day I would like each of you to imagine a wand in your hand and a three-dimensional description of a domain of computer uses in education in front of you. Throughout these final sessions you should indicate by the orientation of this wand what you think the speaker is talking about [or what you wish he were talking about; see Robert Mager's study of *real* learner control of instruction in which the teacher could be turned off!]. I do not care what the domain is as long as we all have the same space described in front of us.

Likewise, each speaker will have a wand in his hand by which he indicates what he thinks he is talking about. The technologists will maintain an electromagnetic sensor in the room which will determine the modal orientation of wands in the audience. If there is no single mode, or if the mode does not agree with that of the speaker, then the circuit automatically introduces feedback into the audio system, increasing with the discrepancy, effectively cutting back efforts at noncommunication. [Notice the advantages of this technological aid for listeners, which are not present in typical uses of the Edex system and other audience-response devices.]

It may be that the most important contribution of Project CLUE (Computer Learning Under Evaluation) is to bring together different points of view about the instructional use of computers, including the various definitions of CAI, and to provide some common framework for discussion. I believe this can be done without causing one point of view to interfere inappropriately with another, and without permitting conflicts to shut down communication. On the contrary, the contrasts seem to improve the climate for new thinking and exchange.

Networks of ideas are not easily described, however, especially in a linear presentation. I wish I knew an effective way to provide some kind of structural representation of where the speaker is now, where he might go next, and what other directions might be taken at another time by listeners having access to the same base of information the speaker used.

For this talk I would lay out a map of information resources with annotation and comment [see the appendices of Volume I of Project CLUE], then draw in another plane to provide a guide to the various statements of position or point of view [Chapters 2 through 7 of Volume II] and, in a third slice of the space, set out particular recommendations for consideration by this conference [selections from Volume I, Chapters 3 and 4].

PROJECT CLUE

My first set of pointers to paths not taken should provide reference to the talk I wrote before I came; one part of the space of this hyperspeech includes all the information I have about Project CLUE. You have an outline of the documents in preparation [reproduced at the end of this text] and many of you have received document drafts from me.

About forty percent of the Project CLUE documents have been distributed in near-final form, including appendices which describe the procedure, resources, and domain of the project. Those of you who were with me in any of the three meetings on computers and education just previous to this one *[Computers in Undergraduate Science Teaching,* Chicago, World Conference on Computer Education, Amsterdam, and Education Sector of the ACM Unconventional Convention, New York City] know that large numbers of draft copies of these materials have been distributed.

The intent of this critical survey was to provide useful information and guidelines for people planning projects or reviewing proposals. There is a long story about origins and objectives of Project CLUE and how I tried to orient the effort in line with the needs of people working in the field, not just those in the Office of Education reviewing the proposals. [I have not written this down so the only reference I can provide the curious reader is personal conversation with me.]

Domain for Discussion

The frame of reference *[Domain of Computer Use Defined for Project CLUE;* Appendix D] has been very useful in some recent discussions. However, it is too late in this conference to introduce it now. I will label and point to three perspectives taken: modes of use, dimensions underlying those modes, and the relative importance of behavioral, computing, and information sciences for the design of learning activities and the support of scholarly tasks within an area of study. These perspectives can be inferred from things said at this conference; but I hope interested readers will follow the pointers to related printed information.

Many writers have prepared schemes for classification of modes for computer use. To help a reader new to this area organize his thinking and handle the various sets of terms used throughout the publications, I have prepared a list which seems to encompass ten published versions of "modes." These different classifications find use locally and I see no advantage in "standards" for this terminology. However, the following listing helps me to organize the domain for discussion and for drafting

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recommendations:

Instruction and Learning Process
- Drill
- Skills practice
- Author-controlled tutorial
- Testing and diagnosis
- Dialogue tutorial
- Simulation
- Gaming
- Information retrieval and processing
- Computation
- Problem-solving
- Model construction (procedural)
- Display construction (graphic)

Management of Instruction Resources and Process
- Student records: selection and summarization
- Materials files: retrieval via descriptors
- Desired outcomes, job opportunities, interests, etc.

Preparation and Display of Materials
- Procedures for generating films, graphs, etc.
- Laboratory for developing and testing text and graphic materials
- Procedures for generating of text on an individual basis
- Procedures for automatically editing and analyzing test materials for new uses
- Information structures for representing knowledge, objectives, and materials

Other Uses
- Educational administration: accounting, scheduling, planning, etc.
- Educational research: institutional, sociological, psychological, etc.
- Applied uses: science, technology, management, banking, production, etc.

The criteria to be used for classification according to the various schemes put forth in published writing have not been clearly expressed. This is not surprising, since in most cases these classifications are used only as illustrations of what might be done. I find it much more interesting to determine the underlying assumptions from which categories have been derived. Some set of essential dimensions should prove to be more helpful than the total of the classification schemes. The following dimensions of use and their relations to each other are discussed in Project CLUE, but this tentative conception is not exhaustive or theoretically comprehensive:

- Program (and learner) control
- Diagnosis and prescription by automatic procedure
- Variety of functions available to users
- Type of interaction between learner and system
- Role of the computer for the individual serviced
- "Naturalness" of the communication between the learner and system

These six dimensions can be viewed as defining a space or domain of computer use, and the modes usually mentioned as simple categories (drill, tutorial, dialogue, socratic, simulation, learner-directed, etc.) are more appropriately described as filling some part of this domain. I have used this conceptualization in a tentative way to establish among users a broader perspective on computer use, and to open up new possibilities for computer service to learners.

It has been fashionable to speak of the psychological order of curriculum material and the contribution of learning research and theory to instruction. However, if one's R&D purpose to to serve college instruction, he should not try to solve the difficult psychological problems of diagnosis and prescription in computer-controlled instruction. The practical approach to computer use in the instructional process is to make the information-processing tools and data bases directly available to the learner and let complex human skills and judgment take over. An overzealous psychologist might try to engineer the stimulus-response chains to the last microresponse, and then assess outcomes only within the limits of "objectivity." A research-oriented management might divert operating resources into educational and psychological studies of factors that have little effect compared with the advantages of time and structure obtained from reformulation of curriculum, and the amplification of performance based on powerful information-processing tools oriented to the subject of study.

Similar reservations have been expressed about the contribution of computer scientists, and the diversion from educational goals and instructional procedures for the attractions of a particular technology. I have argued that the scholar-teacher should remain in charge of the introduction of computer technology into the teaching and learning activities, attending to uses of computers in his area and study, and to the advice of experts on technical matters of system limitations, new information-processing capability, data for revision of materials, parameters of man-machine interaction, etc.

Guidelines for Current Uses

I agree with many of the comments made this week about desirable kinds of computer use; I would like to add emphasis by proposing a set of five guidelines. I will not try to report the official findings of Project CLUE [it requires considerable care to represent in one place a variety of points of view] but give you my own impressions, interpretations, and personal views on how computing should contribute to the instructional process in colleges today.

The use of the computer by students as a tool for learning and problem-solving can be recommended strongly. Certainly this kind of use accounts for a large proportion of allocations of computers for instruction, which is not surprising, since learning tools appear to obtain a great improvement in performance and a favorable change in attitude in return for the investment in time and computing resources.

Management of records and materials, preferably by students directly rather than through teachers and administrators, is a promising application. Any program of instruction that allows some flexibility in learning approach and rewards student initiative requires management of large files of records of student performance, and information about materials and learning exercises on an individual basis. Some projects have assembled files of such size and complexity that the computer is justified for reason of economy, reliability, or accessibility of benefits to individual learners.

Some students have special needs for whom the presentation of instruction (exposition or remediation) via the computer may contribute significantly to learning and favorable attitude. When a student lacks motivation or suitable orientation to the ordinary self-instruction resources, the machine provides a gentle pressure to proceed and to respond at each point of the essential sequence of instruction. [Nevertheless, one would wish to achieve for these students sufficient independence of thought and suitable motivation to proceed with self-learning experiences apart from computer tutorials.] For students lacking essential skills and opportunities for learning from present-day language laboratories and group instruction, the careful sequencing and additional response processing done by computer systems appears to help.

Research on instruction and the development of instruction materials certainly should be pursued where it makes real contributions. It is not necessary that the computer contribute to the learning of individual students; its justification lies in collection or analysis of data, opportunities for more complicated research designs, processing and summarization of data for the designers of learning exercises, etc. [The presently critical attitude toward CAI of a tutorial nature for ordinary students in schools and colleges should, if anything, encourage increased investment in research on instruction and learning. After the process of learning is better understood and some models of instruction have been devised, we may find tutorial use a significant tool in future educational systems.]

New information-processing techniques for providing diagnostic, tutorial, and other aids to individual learners should be explored. The application of findings in the computer-science areas of artificial intelligence, natural-language processing, and question-answering systems should be pursued vigorously for the benefit of educational uses.

I have developed a strong personal interest in working on new information-processing techniques in education and editing a special issue of the IEEE *Transactions on Man-Machine Systems* devoted to viewpoints on instructional use of computers, December 1970.

There are other paths to follow through the material of Project CLUE, but the more interesting trace to put forth in the limited time (and space) for my presentation is through the topics and issues I recall in the base of information assembled by Project CLUE, but which may have been passed over too quickly in the sessions of the first two days. This is not a report of Project CLUE *per se* but an attempt to interpret or select some of the additional issues that people may want to explore in discussion this morning or in future deliberations.

Hardware

1. Insufficient attention has been given to analogue computing and hybrid systems. [These kinds of resources are considerably more important in USSR computing activities than in the United States.] I have seen very effective use of analogue devices on the Michigan campus and although used primarily in engineering, the implications for modeling and simulation in social sciences are significant. Especially important are the hybrid systems which use digital (alphanumeric) processing

for interpreting user design and control of the analogue circuits.

2. Videophone (Picturephone, by Bell) and many other instances of mass developments for the consumers may dominate educational systems. Educational specialists tend to overlook the extent to which a commercial achievement can swamp the educational development effort. [Consider the impact of audio-visual media such as films, television, radio, and recordings on education in the broad sense. I cannot believe that the child, indeed the college student, is more influenced educationally by these media within the institutions than without.] Designers of educational systems must keep watch of a variety of delivery-system options, and give careful consideration to the implications of commercial information services and entertainment systems that have built in educational computing activities.

3. Specialized computing systems can be configured better to serve specific tasks or laboratory exercises. Future learning environments should combine the convenience of specialized systems with the open-endedness and innovation of general-purpose facilities.

Software

1. Extensibility or extendability of programming language should be viewed from a user's orientation. Presently the research-and-development facilities have been tuned for the advantage of specialists in computer science. Extensibility is one important means to achieve programming convenience and transfer without giving up flexibility [Volume II, Appendix D, *Notes on Computer System Design for Instructional Use*].

2. Transportability, or a general facility for getting software from one situation and operating system to another, needs more discussion and then action. Project CLUE documents go into this in some detail [Volume II, Chapter 7, *Documentation and Distribution of Information and Learning Materials*].

3. Creation of problem-solving environments, which should be distinguished from particular programming languages, is possible through the use of specially adapted command conventions and data structures. Computing resources can be arranged in convenient, task-oriented packages for use in solution of problems and exploration of data bases, as well as in nonspecific, procedure-oriented languages.

4. The artificial distinction between batch and interactive processing should be eliminated. Many systems already provide convenient means to move to the mode and terminal device most suitable, and programming languages will provide further support for optimum use of human time and computing resources.

User Support

1. Distribution of noncomputer supporting services is a difficult problem, certainly in regional networks, also in local facilities which require a user to go some distance for documentation. [Psychological distance of computing centers from users has caused more problems than physical distance.]

2. Training and assistance for remote users of computing facilities should receive special attention now. Projects which put most of their resources into system development may find they have elegant software and communications which are unused.

3. Responsiveness to changes in users and institutions is a discriminating measure of an effective system or language. An individual who learns about computers with a very simple language often cannot get away from it in his future use of computers. He may become fixed on its simple characteristics and not open up to new developments. The composition of college enrollment and the sophistication of learners are changing. Some projects may be building to meet present needs that will have been taken care of in other ways by the time the design becomes operational. [It bothers me, for example, to hear at this meeting about extensive planning for a major CAI course to provide college freshmen with an introduction to computing. Before that course and system are operational, most students will be taking a computing course in high school!]

4. Institutions should seek possible multiplier effects achieved by working with teaching fellows and their trainers. Ideas inserted at the level of supervision of young instructors can multiply their introduction into college teaching manyfold.

5. The contribution of professional societies to user support cannot be overemphasized. If institutions, particularly colleges and universities, are to effectively introduce computers into teaching and learning activities, professors must feel they have the support of their departments and administration, and this may be achieved best through professional societies.

Network of Users

In much of the discussion this week the term "network" should be replaced by "distribution system." Computing resources are used in education as television has been used for broadcasting. A regional computing service (or the simple, star-burst network configuration) obtains some feedback from individual users and individual sites. However, insufficient attention has been given to the advantages of linking users directly to one another in order to build networks of users.

SOME RECOMMENDATIONS

I want to point to four sets of recommendations from conferences held in the last year: *Computer Contributions to Learning and Teaching,* ACM SIGCUE working session at FJCC, November 1969; *Guidelines for Instructional Use of Computers,* UNESCO Consultation, March 1970; *Recommendations to Member States,* IFIP World Conference on Computer Education, August 1970; and *Advice to Computer Scientists Contributing to Educational Uses,* ACM Convention, September 1970. [Commentary and preliminary reports on each of these meetings have appeared in the issue of the *Bulletin on Computer Uses in Education* immediately following the date of the conference.]

There are many problems with drafting recommendations, especially as part of a conference. I could relate detailed experiences about attempts at UNESCO, OECD, IFIP, and ACM. The distillation of these experiences is that once a recommendation draft has been made general enough to be acceptable it has been rendered ineffective. Perhaps this is not so true in other countries; that is, the nature of the recommendation and the results and usefulness of it are functions of the educational organization in the country.

One particular set of four recommendations directed to computer specialists seems appropriate to introduce here because it provides a contrast and some ideas new to our discussion. Many of the recommendations of other conferences only will confirm things already said here about cost, change in institutions, change in teacher role, etc.

First, programming languages and user packages should adapt to characteristics of the subject being taught, to the particular learning task, and to the needs of the students and the teachers. Educationally oriented computing systems must remain flexible for a time if they are to provide convenience in the great variety of new situations being encountered.

Second, programs to provide computer literacy for all should be supported by, or encouraged and assisted by, computer specialists. Certainly those experts in computer use should give some attention to the incorporation of information processing into all subjects as the tools are found to be useful in learning activities and the scholarly work of students.

Third, computer-science courses should recognize the needs of those being educated and others they may serve. For example, majors in computer science will later teach and design systems but may miss out on the opportunity to work with nonspecialist users during the training period. Potential users of computers should find convenient opportunity to enroll in service courses which are relevant to their needs and require the minimum effort necessary for the tasks they wish to do.

Fourth, community and continuing education programs should receive greater participation of experts. The needs and interests of citizens cannot be put off until the next generation. Sound education about computing applications and the implications of information-processing systems for the individual and society must be available to all ages, and the careful application of computing aids to learning and problem-solving activities should be extended to all learners without regard to age, institution, or geographical location.

WHITHER THE APPRENTICE?

I will close with an image suggested by Nelson's use in his *Computer Decisions* article of a picture of Mickey Mouse playing with the stars and wearing the magical hat of the sorcerer to whom he was an apprentice. As I recall the Walt Disney film, Mickey played with the powers of the universe while his master was away, and spoiled it all by commanding the broom to bring water from the creek and pour it into a barrel in the cottage—a task Mickey didn't like at all. But he didn't know how to stop the broom from carrying in the water, and the cottage was flooded.

I am concerned about a strong tendency to put in the computer those exercises which seem easy to implement and are uninteresting for humans to do. Full courses of tutorial and drill are made operational without reviewing carefully whether the goals and practice exercises are worthwhile for the students at all.

Who is to control this new resource for self-education? Will the learner be in charge, and will he use the tools to his advantage, moving from apprentice status to full-fledged scholar and practitioner? Or will someone else play the apprentice role and risk inundating the learning environment with repetitious and irrelevant tasks? I have assembled the awesome image of an electronic version of the sorcerer's

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broom flooding a learning laboratory full of passive children with useless facts and nonadaptive skills, and the apprentice to this magical technology standing by unable to turn it off. Presumably, the opinions and preferences expressed by those assembled here indicate that the new resources for learning and extended intellectual performance will be used well in the future.

AN EVALUATIVE REVIEW OF USES OF COMPUTERS IN INSTRUCTION
Project CLUE (Computer Learning Under Evaluation)

Tentative Contents

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A PROPOSAL TO CREATE THE NATIONAL INSTITUTES OF EDUCATION

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Mr. Levien advised me by letter that I was to consume between twenty and thirty minutes drawing upon my experience and judgment "to convey an image of the future," with "well-founded speculation" admitted. As far as computers in instruction are concerned, my well-founded speculation on the future has to do with the future creation by the federal government of the National Institute of Instructional Technology and the activities of that agency in bringing the values of advanced technology to education. The ground for my speculation is the work of the federal Commission on Instructional Technology.

The recommendations of the Commission on Instructional Technology are directed to the President and the Congress. This was required by the Public Broadcasting Act of 1967 which authorized the establishment of the Commission. The Commission was appointed in April 1968. It submitted its report, *To Improve Learning*, to the Administration in August 1969. In March 1970, the President transmitted the report to the Congress, apparently without comment either to the Congress or the Commission. Thereafter it was published in government format by the House Committee on Education and Labor [1]. In the near future it will be published, together with a large number of expert papers on instructional technology, by the Bowker Company of New York.

The Commission was composed mainly, but not entirely, of educators, but it represented a wide spectrum of experience and interest. Only a minority had expert knowledge or extensive experience in instructional technology. A competent group under the direction of Mr. Sidney Tickton of the Academy for Educational Development served as the Commission staff. The work of the Commission and staff involved numerous meetings, seminars, and consultations together with the study of many hundreds of solicited opinions and a large number of commissioned papers. (See Appendix G of Ref. 1 for a partial list.) It is probably accurate to say that input was received from most of the nation's top experts on instructional technology, from education, industry, and government, and from most of the leading groups, both public and private, concerned with the future of this field. Though composed over a period of only about 15 months, the report issued from a massive effort to marshal competent knowledge and opinion. Throughout the study, the Commission's attention was fixed primarily on the recommendations to be made to the President and the Congress.

The Commission was generally inclined to the opinion that the quality of American education at all levels, from pre-school through professional school, can be improved and the values of education extended through the uses of what is commonly called "instructional technology," including both conventional mechanical-type, audio-visual instruments, books, and the newer, more sophisticated programming techniques and cybernated instruments. Its study dealt not with particular techniques, as moving pictures, television, or computers, but with the overall values of technical instruments when employed within an instructional system.

Accordingly, the Commission assessed the worth of instructional technology within a context which embraced the entire environment of instruction, including home, school architecture, the education and differential function of personnel, and above all a continuing and extensive program of research and experiment and the packaging of findings for useful application in the schools.

The Commission did not approach instructional technology as an avenue for saving money or as a panacea for all educational ills. It held that only a large-scale use of automated and cybernated instruments can make a material difference in American education and that this will not reduce the costs of education. It recognized also the dangers implicit in the possibility that means could become the chief determiners of educational ends and it stressed therefore the importance of the purpose of education and the goals of instruction being set by genuinely humane considerations.

From the beginning, the Commission saw its task not so much in terms of instructional inputs as of learning outputs. It concentrated not on teaching but on learning. Its concern was not so much with what might be done with a particular instructional instrument as with what kinds of organization of instruction and educational policies, including both teachers and instruments, are necessary for the achievement of instructional goals. Two things were constantly in focus in the Commission's discussion of instructional instruments: First, that the instruments, whether books, television, or computers, are assets in instruction only when they are integrated into and not added on to an instructional program; that success here means a totally planned instructional program involving teachers, assistants, and other instruments; second, that the value of such instruments must be measured in terms of their capacity to achieve clearly specified instructional goals, goals which might be affective or volitional as well as cognitive. Needless to say, the Commission concentrated more on the problem of software, where deficiencies are greatest, than on hardware. This concern is reflected in the recommendations.

In general, the Commission found that technology, employed as in the Commission's opinion it can be employed, can:

1. Make education more productive,
2. Make instruction more individual,
3. Give instruction a more scientific grounding,
4. Make instruction more powerful (I personally object to that term—I would have preferred "effective"),

5. Make learning more immediate, and
6. Make education more equal.

It found that where technology has general value for education as a whole, it has special values for the instruction of the culturally disadvantaged and the mentally and physically handicapped.

The recommendations of the Commission are six in a number. (See Chapter V of Ref. 1.) They are directed especially to federal action by the Congress and are based on the premise that at the present time in the matter of instructional technology American education is still in the horse-and-buggy stage and massive national action is necessary to bring it up to date.

The first and basic recommendation is the creation by Congress of the National Institutes of Education to be fashioned somewhat after the National Institutes of Health and to be administered under the Secretary of Health, Education, and Welfare. (I believe it is the opinion of most, if not all of the Commissioners, that a separate Department of Education should be created, with cabinet status, and which would house the Institutes. This was a footnote item, however, and was not a formal recommendation.)

After intense consideration and extensive study and consultation, the Commission came unanimously to the position that the large national and governmental action necessary to realizing the full educational potential of technology could not be achieved short of a radical restructuring of the federal educational establishment. It held the same view with respect to other elements of the educational enterprise that require extensive research and development and inevitably involve large infusions of public money. The recommendation does not propose the elimination of the present United States Office of Education but would restrict its functions to more routine financial operations while transferring its research and development functions to the Institutes of Education.

The National Institutes of Education would report to the Assistant Secretary of Education and would be headed by a Director appointed by the President and assisted in policy matters by a high-level Advisory Board from inside and outside the government. The Institutes would conduct a limited amount of in-house research and development, but their main activities would be directed to grants for research and development by nongovernmental institutions and agencies both public and private.

The second recommendation, central to the purpose of the Commission, is the establishment by Congress of the National Institute of Instructional Technology as the first of the National Institutes of Education. Other Institutes listed in the recommendations simply as suggestions are the National Institute of Learning Research, the National Institute of Teaching and Curriculum Development, and the National Institute of Educational Management. The Commission described the function of the National Institute of Instructional Technology as "research, development, and application in equipment, instructional materials, and systems, and also in training personnel."

On March 3, 1970, the President sent a special educational message to Congress in which he recommended the creation of a National Institute of Education. Thereafter, the then Commissioner of Education, James Allen, undertook the preparation of legislation for the Administration designed to establish an Institute. With others I was invited by the Commissioner to participate in developing plans for the Institute and can assure you that much careful thought was invested in this project. In the Congress Mr. John Brademas of Indiana introduced HR16262 entitled "A Bill to Establish a National Institute of Education."

I have had no contact with the project since the departure of Mr. Allen from the Commissioner's office. It is my understanding that Roger Levien of The Rand Corporation is presently engaged in doing a feasibility study on the creation of a National Institute at the request of the Office of Education. In testifying earlier before Mr. Brademas' Select Subcommittee of the House Committee on Education and Labor, I expressed the opinion that the creation of a single Institute of Education, as proposed by the President, would lead eventually, and hopefully, to the establishment of additional Institutes to cope with the specialized problems of education.

The third recommendation concerns the responsibility of the National Institute of Instructional Technology to "take the lead in efforts to identify, organize, and prepare for distribution the high-quality instructional materials, in all media, capable of improving education." Here appears a special item dear to the hearts of the Commission members—the establishment by the NIIT of a national center or "library" of instructional materials, with responsibilities for "identifying those areas in which there is a shortage of educational software, and making public these findings; assisting school and college libraries to transform themselves into comprehensive learning centers; and stimulating interconnections (among specialized libraries, data banks, schools, and colleges) for comprehensive and efficient access to instructional materials and educational management data."

In keeping with the Commission's concern for the practical application of the findings of research and experimentation, the fourth recommendation proposes that the National Institute of Instructional Technology establish extensive demonstration projects to exhibit the results of the "wise exploitation of technology." Special attention is proposed for selected communities, such as impoverished rural areas, urban ghettoes, or centers of Indian, black, or Spanish-speaking populations.

Recommendation five proposes that the National Institute of Instructional Technology instigate the development of a massive and comprehensive program to improve the capacity of educators, both teachers and administrators, to effectively employ technical instructional instruments and to prepare specialists in instructional technology.

The sixth and last recommendation proposes that the National Institute of Instructional Technology develop a mechanism such as a National Council of Education and Industry to bring together educators and the education industry to advance the effectiveness of instructional technology by coping with such problems as production, compatibility of equipment, pricing, ethical marketing, and research and experimentation.

The Commission proposed a budget of approximately $565 million for the first year to establish the National Institutes of Education, create the first Institute, the Institute for Instructional Technology, and provide for operating expenses and grants. The breakdown of the proposal is $150 million to launch the National Institutes of Education and the Institute of Technology, including capital expenditures, $415 million for the first year of operations, including $25 million for the National Library of Educational Resources, $250 million for research, development, and application activities of the Institute, $100 million for demonstration projects, and $40 million for the training of personnel. The budget would, of course, include the present research activities of the Office of Education.

REFERENCE

1. *To Improve Learning: A Report to the President and the Congress of the United States by the Commission on Instructional Technology,* Committee on Education and Labor, House of Representatives, U.S. Government Printing Office, Washington, D. C., 1970.

EDUCATIONAL TECHNOLOGY ASSESSMENT—NATIONAL ACADEMY OF ENGINEERING

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A committee on Instructional Technology was formed by the Commission on Education of the National Academy of Engineering in 1967. Its main task from 1967 to 1969 was to participate in a pilot program of Technology Assessment for the Committee on Science and Astronautics of the U.S. House of Representatives under an agreement between that Committee and the Committee on Public Engineering Policy of the National Academy of Engineering. Since the purpose of the study was to develop methodology for technological assessment, the details of the charge were left open. The Instructional Technology Committee decided to restrict its scope to higher education, and to only two aspects of educational technology: instructional television (ITV) and computer-assisted instruction (CAI). Even with this restriction the assessment was considered incomplete and primarily designed to show some of the problems of technology assessment.

The full report of the NAE study of technology assessment is available from the U.S. Government Printing Office[1] for those interested in this aspect of the study. The data base, with a general introduction addressed primarily to engineering educators, was also prepared by the Commission on Education[2] and is available for distribution here for those of you who desire it. This data base is a review of some of the past history in ITV and CAI for higher education, and is in a sense the part of the study most relevant to this program. I won't try to summarize it, however, since it is available in the printed reports and undoubtedly duplicates much of what has been said earlier in this program.

The part of the study concerned with CAI is of course that relevant to this Conference. Yet before leaving the matter of ITV, I would like to point out that the comparison between the two fields was a useful one: ITV is at least a decade ahead of CAI in its development, and some of the problems with the latter field were met in the former in the preceding decade. In both fields there was a preoccupation with hardware before the software was adequately developed. In the early stages of ITV individual efforts were encouraged and it required a standardization phase before programs could be interchanged on either film or video-tape. These are two of the most fundamental and annoying problems with CAI at this point in time except that there seem to be many more variables in the latter medium. Another similarity is that both fields have a potential for cost saving if used on a large scale, yet the first acceptance of both media by the academic community appears to be for improvement of the quality of instruction with actual increases in cost.

Although I do not want to stress the methodology of technological assessment, I think it is relevant to give the questions to which we addressed ourselves, since these are fundamental and open questions for all educators in the use of new media. I should make clear that we did not have time to answer these in an acceptable fashion, even though our committee had on it several competent social scientists, so the questions raised were raised largely on the basis of the experience of those working with the media, and the tentative answers given were based largely upon the opinions of committee members and consultants working in the field. The committee did contain active users of the two media. Some of the questions raised concerning the institutions of higher education were:

1. Will the new aids increase or decrease the costs of instruction per student?
2. Will they result in improved instruction?
3. Will they require major changes in the approach to the planning of physical plants for these institutions?
4. Will they result in a closer tie between various schools as communication links are provided for CAI and ITV?
5. Will these aids result in a destructuring of the curricula because of the possibility of tailoring instruction to the individual much more than at present?
6. Will these media exert a pressure toward a longer work week in schools in order to make better use of the capital investment?
7. Will the educational use of these communication media result in additional needs for channel allocations for both land-based and satellite transmitters and relay stations?
8. Will the high cost of software preparation tend toward increased standardization of curricula and centralization of their administration?
9. Will these media prove especially desirable for the important field of continuing education?
10. Will they be desirable for use with minorities and other underprivileged students where the flexibility could prove advantageous?

The technology assessment report has some tentative conclusions from our committee concerning the likelihood, the desirability, and the controllability of each of these, but I prefer to leave them here as questions for you to discuss or think about.

A similar set of questions was raised with respect to the students:

1. Will the technological aids automatically be looked at as impersonal, or can their potential for freeing the teacher for greater personal attention be utilized?
2. Will the opportunity for individualized instruction be utilized, leading to shorter educational periods and lower costs for at least some students?
3. Will minority-group students see the machine as at least neutral and react better to it than to present teachers?

4. Will student-instructor relationships improve as the instructor becomes more of a manager of the technological aids, leaving measurement to the student and thus minimizing the adversary aspect of student-faculty relationships?

Some of the questions concerning impact on the faculty were:

1. Will the knowledge of computers given by CAI result in more familiarity with computers and better usage for a variety of purposes?
2. Will new methods of copyright protection be needed to stimulate instructors in the preparation of software for the new media?

The following questions were raised concerning the impact on industry:

1. If technological education becomes practical, will industry tend more and more to do its own educating for required skills instead of relying on universities?
2. Will the development of consoles, display devices, and large time-sharing computers for education lead to the large education-related industry that many have predicted but that has so far eluded us?

Our committee found it easy to agree on answers to some of these questions, but impossible to agree on others, or even to plan at this time for the proper experiments to determine the answers. I suspect it will be much the same with this group. Nevertheless the questions are important ones and may provide some basis for discussion in the workshops this afternoon.

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A PROGRESS REPORT ON THE "IMPACT OF TECHNOLOGY ON HIGHER EDUCATION"

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At M.I.T. we are engaged in two studies which form the background for this paper. The first of these is the Associative Learning Project which we've been working on for about two or three years. This has to do with the use of interactive computer terminals to help teach accounting. If there is one thing worse than taking accounting it is teaching it, and the Planning and Control Systems Group at M.I.T. has felt a need to remove the more structured material from the classroom to a more effective teaching device. The first approach was to try programmed instruction text, then regular CAI material was tried, and finally we developed the notion of using a mixture of pedagogical techniques that more nearly match the richness of the material and the desires and competences of the students. This system has been described elsewhere [1] and will not be gone into further at this point. The basic goal that we are striving for is to provide flexibility and richness to the student, the same kind of thing that Ted Nelson [2] has described in his view of the future.

A second study under way at M.I.T. is the Impact of Technology on Higher Education. This is funded by Clark Kerr and the Carnegie Commission and by the Ford Foundation. We are only one year and a half into a three-year study and so we are not at the point of making specific recommendations. We have tried to devise a methodology and define a boundary for this field that recognizes the work that Roger Levien has done in the Rand study and the various other kinds of projects that are under way. The balance of this paper describes the components of the study and the methodology we are using. The paper concludes with the areas in which we will make recommendations. It should be made clear that the study is the *Impact of Technology on Higher Education.* This is much broader than computer technology and is much broader than simply using computers to help in the teaching process. Technology must encompass all of the developments in hardware and software that are relevant and higher education has important components other than instruction.

As an initial step in the project, after our definition of goals and general strategy formulation, we visited a number of major projects in which computers were being used in higher education. This extensive series of visits helped us define what we felt to be a relevant boundary for the project. This boundary and the major segments within it are discussed below.

TECHNOLOGY

Hardware Technology

The first term in the title *Impact of Technology on Higher Education* has been defined to have three major components with a number of subcomponents within it. The first major component is the hardware, and within this there are two categories: computer hardware and other forms. Other forms of hardware include such items as remote TV, video tape, microfiche technology, and the like. For the purposes of this paper these are not elaborated on at all, but they obviously have an important part to play. The computer hardware is obviously the most important because of its flexibility and adaptability and because of the fact that one can build in a certain amount of intelligence.[3] Another paper has summarized our views on where we stand with the technology, but one or two of these points should be stressed. Within computer technology there are three major components that we think are going to be significant.

Terminals. The first of these hardware developments is that of low-cost terminals.

In the terminal field we now have good, cheap, reliable, interactive graphic terminals such as the IMLAC, ARDS, and Computec terminals. These sell for about $7,000 each and are obviously usable in an educational setting. We are not constrained to wait for the more desirable "Bitzer" terminal in two or three years from now, nor is there any need to invest large sums of money in special purpose devices.

Communications. The use of computer networks and the possible availability of microwave links across the country are both developments which, although with us in part, are obviously going to have increasing importance on what happens in the future. For example, if University Computing Companies' application to the F.C.C. is upheld then a microwave network will be available which will make enormous differences in wide-band communciation costs.

Computer Mainframes. The third hardware development is in computer mainframes. The important feature of part of computer technology is not the issue of whether it is better to have a mini, midi, or maxi computer but rather, for any given user, the realization that he has a spectrum of power and it is possible to get the mix correct. This means that the economics of any given situation can be very much better than they used to be as the appropriate form of computational power is being brought to bear.

Software

The second major component of technology is the software. This has a number of different subcomponents and it is extremely important to separate these. The first is language availability and in this one included operating systems as well as the various author languages. This area is basically under control and well developed. We do not see any need for concern. However, in the remaining three subsections it seems that there is a need for more work, that a lack of understanding exists, and that there is a lack of definition of the problem area. These next three subsections are critical for all of us in the field to understand clearly.

Instructional Software. By instructional software we mean the set of material that the student sees as he tries to work with the system. The one very depressing aspect of a lot of the projects currently under way in this country is the almost superhuman single-mindedness with which various researchers have addressed themselves to the problems of using computers in instruction. A number of very fine efforts have been made to use computers to teach students. These have often involved tremendous amounts of money and a lot of work by some very dedicated people and many have produced some quite interesting results. The depressing point, however, is that very often the prime movers behind the project view their solution as *the* solution. That is, they view their technique, their kind of dialogue, or drill and test or whatever, as *the* answer, and somehow, it is expected to apply across the whole range of material we have in universities and be equally appropriate for a number of different kinds of students. Obviously, this is not the case. It seems useful to think of a spectrum of different forms, or different types, of pedagogical techniques which will be appropriate for different kinds of material and different kinds of students. This identification of the range of techniques and range of material is something which is not very widely regarded as important and not much effort has been spent on it.

For our purposes we are dividing instructional software into three fields. The first of these is what we term "traditional"; that is, the field in which most of the work that has taken place so far falls. This would include such things as anything written for an IBM-1500 series system in Coursewriter, all of the drill-and-practice, tell-and-test, fill-in-the-blank, multiple-choice kinds of material. These are useful techniques, and very appropriate for a certain kind of material and a certain kind of student.

The second class we call the "responsive systems." These are the kinds of systems that are not exclusively author-controlled, but where the student has the possibility of exploring his own ideas and working through a semantic net of concepts and ideas in his own way and at his own pace. Progress in this area is rather sparse, but work by Uttal, Grubb, and Zannetos, et al., indicates a new direction in teaching approach. The ability to allow the student some control over his *direction* as opposed to the traditional approach of control (at least in some cases) only over *pace* is an important characteristic.

The third category is the set of software that allows for an enriched environment. That is the software is designed to allow the student to engage in dynamic problem-solving or let him use simulation to identify and experiment with a whole new set of concepts and phenomena that he could not understand as well without such an enriched environment. Examples of this are things like physical phenomena, particle physics, and the laws of motion. Another might be the use of games in a business setting and all the others sorts of things that can be used to enrich the environment the student is dealing with.

A good deal of work has been done in the first and third of these fields, but very little is happening in the responsive systems area and that is probably where the greatest potential lies for use of computers in teaching at the university level.

The Management of Learning. The second major form of software technology we are concerned with in this project is the management of learning. The use of the computer is important to the management of the learning process. There are two aspects of this. The first is the fact that by using terminals we do have a trace of the student. This is an extremely powerful feature of computer technology and the one that will allow us to "bootstrap" our way up into quite powerful systems. That is, these traces can be used as an aid to redesign the material, to let the faculty member understand what is good and bad about what he is building, to allow the student to understand characteristics and attributes of his performance that will let him improve over time. This whole use of the trace of the student as he learns as an aid to understanding what we are doing in this field is one that has hardly been exploited at all so far.

The second characteristic of the management of learning, of course, is the use of Computer-Managed Instruction (CMI) and Individually Programmed Instruction (IPI), in managing the students' progress through the program. This is not, perhaps, very useful at the college level from the standpoint of the student being monitored by the school or professor. It is very difficult to prescribe good modules of instruction. We do not have clear prescriptions and clear objectives for the way that these projects (CMI and IPI) are attempting at the secondary-school level. Without clear precise objectives, appropriate modules of material, and ways of testing to see if objectives have been met, the CMI and IPI approaches are not particularly useful. It might be that this technique would be useful for the *student.* That is, if the CMI approach was taken with an idea of giving the student advice as to what he could do and where he was, it might be more helpful than if it were used by the *school* to help the student. At the moment this student-centered approach has not been consistently explored, and it remains to be seen whether it will be effective.

Administration of Institutions of Higher Education. This third area of software technology is perhaps the most neglected area of all. The application of computers to the managing of the planning and control parts of the senior administrations' tasks in governing a university has been very sparse. Some institutions have used computers quite successfully for information systems to handle the ongoing structured tasks, such as payroll, accounting, and so forth. Very few instituitons have made any serious effort yet to use computer support for the senior managerial levels, and the more unstructured tasks. Long-range planning, budgeting, cost accounting, and other systems to support important managerial decisions are not very advanced. Business organizations of comparable size are typically much further advanced. A great deal of software and technology and systems methodology could be transferred directly. So far there has not been much willingness to invest in these systems.

Educational Systems

The third major category in the technology field is the educational systems area which has the two features of systems analysis and implementation processes. Both the hardware and software discussed previously need to be combined in a working system and applied at the university level. This has not been thought of as a large-scale systems problem. As such it involves all the analysis, detailed planning, and care with objectives and design strategies that one would expect in a normal business setting. This area, perhaps originally designed to be supported by the learning corporations, is still one in which very little action is taking place. Educational systems remain very much of a dream and are poorly understood.

HIGHER EDUCATION

The components of higher education that we think are important for our project to deal with are described below. Each of the areas identified will be impacted by technology as it has been defined in the previous comments. The question remains as to how, when, and what we can do to facilitate the restructuring of the organization to encourage this to happen sooner rather than later. This issue is discussed in the final section of this paper. The major components of higher education that are important for our purposes are (a) content, (b) the learning process, and (c) the learning package.

Content. There is a growing set of material that must be transmitted at the university level and the impact of technology is such that the content of this may well change. That is, we can teach different kinds of concepts and get across different kinds of issues through the medium of the machine. This is particularly obvious in the scientific disciplines where it's possible to give students a whole new idea of what microbiology or high particle physics is about. For example we no longer teach manual methods of matrix inversion to our graduate students. Any student who wishes to invert a matrix can use any one of a number of computer programs. He should know the concepts but has no need to know the mechanical details. This shift in the *content* of relevant material for a field as a result of technological change can be dramatic.

The learning process. The learning process is at the moment regarded by almost everybody in the field of technology and learning as being a black box. A black box which is not understood and although it is not easy to see how to build a good model of the learning process, it is quite clear that this has to happen. That is, the learning-teaching aspects of higher education are extremely important. It is difficult to see what kinds of impact computer-based teaching will have unless we understand what the component steps of learning are. If we understand what these are, then it will be possible to assess the impact of technology. Thus we will be able to redesign our computer-based systems to be more fruitful when used in a teaching mode. This is an extremely important step, one in which virtually no work at all has been undertaken in the country. We have included in our study (3) a seven- or eight-step process model of the learning process. This is *not* meant to be a good model of the learning process, but it will be our first step toward this. We regard it as important to take a stand on this issue although we do not think that the model which we have developed is correct.

The learning package. The third of these components of higher education that we think is important is the learning package, that is, the mixture of curriculum and program that makes up the content of the students' education. This is currently compartmentalized, often in a rigid fashion, with prerequisites and sequences of steps through a program that do not offer a great deal of latitude to individual students. In many cases the package has not changed significantly for a large number of years. The technology offers us the possibility of removing many of these arbitrary boundaries that exist, and opening up the material to more nearly match the students' interests and the requirements of present-day society. There are several other components that are significant. Obviously the organization with its people, dollars, and fixed assets exists in some way to transmit the three components above and make them available and usable to the client, that is, the student or faculty member. This transformation sometimes seems to take place *despite* the organization. It is certainly true that a double-headed arrow is appropriate in this regard. That is, the organization limits what we can teach in the way of content, what happens in the learning process, and what the learning package looks like. Similarly, the content of the learning process and the learning package help determine the organization structure. The previous remarks also hold true for the research activities of the university, and there are, in addition, a whole set of external forces that have an impact on the institution of higher education; forces such as governmental pressure, the trends in the economy, population, and so forth.

Our first task, then, is to understand what these components are, to understand where technology is affecting them in their present state, and to worry then about what will happen in the future. This will involve projecting the key variables in the technology, and looking at what they may look like over time, and then assessing the impact these will have on the components of higher education as we have defined them here.

AREAS FOR POLICY RECOMMENDATIONS

We are not ready to make policy recommendations at the present time but there are some things that are immediately obvious at this stage of our project. The first of these is the hardware, and by hardware I also mean in this case the operating systems and basic languages that belong with the hardware. We are convinced that the hardware is available and of adequate quality. There are lots of interesting things that we can do with the technology as it now stands. It is important, then, to focus on the *hard* problems of how to use this technology effectively and not on the problems of expanding the technology for its own sake. This point seems to be in need of stressing across the country although it is not surprising that it occurs as the technology can be very seductive despite its cost in terms of manpower and dollars.

The second immediate recommendation is that we stop installing *operational* systems; that is, that we continue to treat each project as experimental and focus our attention very carefully on being honestly wiser as a result of using the computer-based system. The writing in the field and the discussions at conferences are singularly lacking in the willingness of the researchers to state the things that they have found wrong with their ideas, to state the limitations of their techniques, and generally to be honest with themselves perhaps, and certainly the rest of the world, in terms of the kind of impact and the sorts of conclusions they really can draw. In a sense, this current lack of money to conduct research is a good and healthy phenomenon. We are being forced to think about what we are doing, and we do not have the money to go ahead and build operational systems. It is certainly a very crude mechanism to accomplish this re-thinking of our activities, since the money will be cut from good projects as well as from bad, but on balance it may be better to have no money at this point than to go on funding at the kind of levels we have seen over the past few years. Certainly, the last thing that is needed at the moment is massive federal money being poured into the creation of operational computer uses in instruction.

AREAS FOR LONG-TERM RECOMMENDATIONS

Identification of Problems and Directions

The first suggestion that we would have is that effort be spent to develop a map or a focus for the area. There are a large variety of activities, a large number of institutions, lots of research projects, and yet we have very little concept of what the field is and what the real questions are. The work is fragmented, the disciplines are fragmented, the money that has been spent by the federal government has been spent very often in small grants to a lot of institutions for limited periods of time. Very little has been pulled together in coherent form out of all the activity that has taken place thus far.

For example, in a very much oversimplified way we could look at the previous papers at this conference as identifying what they thought to be the important problems. These fall in the following general lines:

The first speaker stressed that the computer was the problem, the next talked about the terminal being the problem, then one or two speakers got onto the program and languages being the problem. Then the emphasis was on the faculty and administration who were the bottleneck and the major problem, and finally, the student was mentioned as being the problem. We would suggest that perhaps we do not know what the problem is. We ought to devote a great deal of time and effort and resources to pulling together what we do know, and being clear on what the issues are and what some strategies might be to solve these issues.

Fundamental Research

The second area for recommendation is that we ought to have some fundamental research that will go on in parallel to the activities mentioned above. As was mentioned, we simply do not understand the fundamental aspects of the learning process and we must invest a lot of resources and effort in understanding this process.

The second area in which we should invest fundamental research is the identification of the spectrum of material, spectrum of students, and spectrum of pedagogical techniques, and the working out of some way of linking these three different ranges of variables. The material that we want to teach runs anywhere from facts to feelings. The students have a whole range of styles and we have this mix of pedagogical techniques that we can use. We have to develop some notion of matching these together.

The third area of fundamental research is probably to think through the kinds of material that we simply will not be teaching in the future because we have put the tools into the computer. It will be useful to plan this transformation, for example, we will perhaps not need to learn how to solve differential and integral equations in the future because we will have systems that will solve the mathematical equation for us. This sort of fundamental long-range re-examination of what material we ought to be teaching, and what material we ought to be removing from the curriculum altogether, is something that has not taken place in very many disciplines.

Search for high-leverage points. The third area for recommendation is that we must spend time worrying about where in the current structure of higher education we can find leverage points to accomplish the kind of change that really has to take place if we're to keep pace with the forces around us. It is apparent from the earlier papers that the incremental approach is not going to work. We cannot simply have more of the present CAI systems, or replicate the kinds of activities that are currently going on. It is not effective enough and it will not occur fast enough. Similarly a frontal attack with masses of money poured into universities in an attempt to get them to develop a lot of new material quickly is also likely to fail. By the same token the "end run" that was suggested in an earlier paper is going to be a very expensive proposition if it results in bypassing universities and going directly to the 50 million students that were mentioned, many of whom do not realize that they are in fact students.

A strategy that may be more sensible would be to use the power that does exist in our present institutions and find ways to get leverage. An example of the kind of thing that is being referred to here is Weizenbaum's example of the use of "daylight savings" time. Rather than pass laws and go to a great deal of effort to encourage the use of extra daylight in the winter, a simple decision was made years ago to move the hands of the clock one hour. This subtle administrative mechanism immediately gets everybody to the factories and offices earlier and produces a complete change throughout the system. This sort of very simple and highly effective maneuver is not likely to exist per se in the higher education field, but it is that sort of thing that is desperately required at this point. Examples of such techniques might be to have a new degree structure, to have two-year packages of education that can be collected by students in modules as they are required. Or, it might be that the government should make grants of $500/month for all those who are laid off from their jobs, if they were interested in enrolling in institutions of higher or further education. Or perhaps a new reward scheme should be implemented that allows junior faculty and others to invest heavily in developing materials to improve the effectiveness of the educational process.

We will have to explore these and other ideas as to their feasibility and desirability, but there is no question that effort must be spent to find such high leverage points in an attempt to make some progress in a field in which we are at the moment very far behind.

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INSTRUCTIONAL USES OF THE COMPUTER IN HIGHER EDUCATION

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INTRODUCTION

The Carnegie Commission on Higher Education, chaired by Clark Kerr, was established in 1967 to study and make recommendations concerning the future of American higher education. In carrying out its charter the Commission has sponsored a number of studies of various aspects of the higher educational enterprise. One of their concerns has been the role that technology—especially computer technology—might play in extending access to quality higher education throughout the country and in raising instructional quality or reducing its cost. Consequently, early in 1969 the Commission requested Rand to undertake a study of instructional uses of the computer in higher education. We were to consider the ways in which the computer could be used, review the current state of use, and examine the possibilities and prospects for instructional uses in the future. Early in 1970 the National Science Foundation and Rand provided additional support for further work and for the convening of this conference. The final report of the study will be available in 1971. This paper is a preliminary report on the third aspect of Rand's study—an examination of the future of instructional uses of the computer in higher education.*

Prediction Versus Prescription

There are two ways to approach estimates of the future: predictively and prescriptively. A *predictive study* attempts to estimate what *will be,* taking into account the probable developments in technology and institutions and seeking to discern the most likely outcome, but not suggesting actions that might make one or another outcome more probable. A *prescriptive study,* however, begins with an idea of what *ought to be* and attempts to make recommendations that will help to achieve that desired goal. Since one major objective of the Carnegie Commission-sponsored study has been to derive recommendations for action by higher education, industry, and government, we have adopted a prescriptive approach. The future of instructional use of the computer in higher education is not fixed and immutable. We can shape it to serve our objectives.

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* The conclusions of this study are directed explicitly to higher education. Quite different conclusions and recommendations might be warranted for elementary and secondary education.

Objectives for Instructional Computer Use

What are those objectives? The answer to this question is not simple; but even to begin to discuss it adequately it is necessary to be more precise about the meaning of instructional uses of the computer. With regard to objectives, one categorization of those uses is especially important: that which distinguishes between instruction *about* and instruction *with* the computer.

Instruction about the computer occurs in fields such as engineering, business, mathematics, and computer science, in which the computer itself is the *subject* of study. There are, in fact, three subcategories of such use: *specialist* instruction, which serves those prospective engineers, programmers, analysts, and others who will devote their careers to some aspect of computing; *service* instruction, which serves prospective scientists, businessmen, and professionals who will use computer tools in their future careers; and *survey* instruction, which serves all students, who as citizens and consumers will have to be aware of the computer's benefits and dangers.

The need for instruction about the computer comes from outside higher education; it derives from the needs of society, in which the computer is widely used, for specialists trained in its use and for a populace aware of its properties. Consequently, *the future of instruction about the computer in higher education depends on society's future needs for computer specialists, users, and literates.*

The objective of national policy concerning instruction about the computer, thus, should be to insure that higher education is providing adequate training of a sufficient number of persons to meet the national needs. The *relative* cost of computer use (as compared with other modes of instruction) in instruction about the computer is not a major question, since the computer must be a part of such instruction in most cases, just as expensive laboratory equipment is an essential part of teaching in the physical and biological sciences, engineering, and medicine. The *total* cost of computer use is, however, a major problem, especially in these times of expanding computer use and tight higher education budgets. To the extent that higher education is meeting an important national need through instruction about computers, then, some national subsidy program from industry or government might be warranted. However, this study has not been principally concerned with instruction about the computer. Our attention has been focused on the next category.

Instruction with the computer has the potential to change higher education significantly. In such uses the computer is being employed as a tool to assist the teacher or the learner during the instructional process. The computer may present tutorial or drill material, aid in the simulation or gaming of a complex process, assist in the solution of difficult practice problems, keep track of student progress, or give review tests and examinations.

The need for instruction with the computer comes from within higher education; it occurs because the computer possesses some advantage over alternative modes of instruction: teacher, textbook, television, or other technology. The advantage may be that it is more effective, or less costly, or some combination of both (including less effective, but also less costly). Consequently, *the future of instruction with the computer in higher education depends on its advantages relative to alternative modes of instruction.* This fact is often summed up by saying that the computer's use must be *cost-effective,* which means that for a particular use, as compared with alternatives, the computer provides the most satisfactory combination of cost and effectiveness.

The objectives of national policy concerning instruction with the computer, therefore, should not be to encourage the use of the computer for its own sake, but rather to see that access to the computer is possible wherever its use would be cost-effective *and* to see that its use is refined and improved so as to broaden the range of circumstances in which it can improve instruction. (These should be the objectives of national policy with regard to other modes of instruction as well.) The *relative* cost of computer use in instruction with the computer is a major question; the computer justifies itself only through advantages in cost and effectiveness. However, the *total* cost of computer use is not a major problem; since it is only one mode of instruction, there is no greater reason to subsidize its use than to subsidize any other mode. National policy might require the subsidy of higher educational instruction in general, but the choice of teaching method within that general subsidy would seem to be better left to the discipline, institution, and instructor.

The task faced by a prescriptive approach to the future of instruction with the computer, then, is to discern the major factors and alternatives that will affect the way in which the computer participates in the instructional process and to suggest those actions that would seem most likely to serve the objectives of national policy. The major factors and alternatives can be broken into four categories:

- The computer's capabilities and costs.
- The methods for providing computer service.
- The methods for providing instructional materials.
- The effects on higher education.

This paper will describe our study's conclusions about the likely developments in each of those categories and then suggest some actions intended to bring about the fullest realization of the computer's potential for efficient participation in the instructional process.

COMPUTER CAPABILITIES AND COSTS

Our major conclusion with regard to the likely future state of the computer art is that it will not be a problem or impediment to the computer's effective use in instruction.

Hardware

Computer hardware capabilities and costs are already, and will continue to be, completely adequate to support a sufficient number of "interesting" instructional uses of the computer. Of course, as capabilities increase and costs decrease, a wider and wider range of uses will become feasible, but the effect will be to move us further along a continuum of use along which we have already advanced, not to cause a sharp increment in the attractiveness of computer use.

Most of the desirable and anticipated advances in computer hardware are likely to occur as a result of the demands of uses outside of education. The two most critical areas for education are terminal devices and communications. While available terminals do not yet satisfy all of the needs of educational use, the competition and rate of improvement in terminals is high. Communication problems, especially the need for reliable and inexpensive telephone connection between campus terminals and remote computers, may prove more serious. Nevertheless, there are developments, both administrative and technological, that promise to ease these problems during the next few years.

Software

The situation with respect to software capabilities and costs is similar. We already possess the programming tools to do many (not all) interesting things with the computer as an aid to instruction. The current generation of operating systems and programming languages is completely satisfactory to support a wide range of effective instructional uses. Indeed, they provide far more capability than has been used. We must learn how to exploit that potential more fully.

There is one direction of software development not yet being explored vigorously that warrants further effort in the service of education: development of software tools to aid in the flexible employment of the computer as a medium. The computer when connected to a television-like terminal becomes a medium that differs from text, television, film, or phonograph in its ability to intermix text, still pictures, and motion pictures and in its capacity to ask for and respond to human guidance in determining the sequence of images and content to be displayed. This flexibility and responsiveness might be employed to create materials that each user could individualize by tracing his own path through a complex, highly interlinked network of text or pictorial segments. (This concept has been suggested, described, and explored by Theodor Nelson, who coined the term "hypertext" to describe the network of text or pictorial segments.)

Two Major Trends

In addition to the satisfactory basis for instructional use provided by the current and likely future overall computer state of the art, two major trends in computing hold out special promise for instruction with the computer. The first is the development of *large, centralized computing facilities* whose use is shared by many remotely situated customers linked to the computer via telephone lines. The second is the development of *small, cheap minicomputers* that can be programmed via an easily exchangeable medium such as magnetic-tape cassettes like those used in sound recording. Each of these modes of use—highly centralized and highly decentralized, as well as combinations of the two—offers considerable potential advantage for instructional use, because each offers a convenient way to disseminate instructional materials beyond their place of origin: storage of the materials in the large central computer automatically makes them available to any of the remotely situated users; cassettes containing instructional materials for the minicomputers can be distributed and sold or rented like books or records. These two technological developments, then, provide the basis for creating a *market* for computer-based instructional materials not unlike the one that exists for textbooks. As we shall explain shortly, the creation of such a market seems to us to be the critical step in achieving the desirable level of computer use in instruction.

PROVISION OF COMPUTER SERVICE

We can now turn our attention to the campus and consider the first of two interlinked questions: How will computer service be provided? How will computer-based instructional materials be provided?

Computer service is needed on campus for several categories of use: administration, research, and instruction. Frequently, the same service meets all three needs. In many instances, however, separate services for administration or specialized research uses exist. In this discussion the objective will be to determine the desirable means of providing service for instruction; the other uses will not be considered.

Consider a college or university seeking computer service. It has four choices:

- Centralized campus facility—serving all its needs with a centrally managed computer.
- Decentralized campus facilities—letting each user or group of users acquire its own computer.
- Regional networks—sharing the use of a computer managed in conjunction with a group of other institutions.
- Commercial time-sharing service—sharing the use of a computer managed by a commerical computer service organization.

Since we have put aside administrative and research uses, we can consider these four alternatives on the basis of a single criterion: Which will provide the best instructional service? But instructional use of the computer requires two things:

1. Computer service.
2. Instructional materials.

The core of the argument we make in this study is that these two things cannot be separated. Choices made with respect to one must take the other into account. Thus, in choosing a mode of providing computer service we must be guided by the implications for the provision of instructional materials. To see how this might be done, let us consider each of the four choices above.

Centralized Campus Facility

The centralized campus facility is the most common means of providing computer service at present. Experience leads us to expect that most of these facilities will be idiosyncratic and non-standard. That is, only a very few campuses will have computer facilities similar enough to permit easy exchange of programs—that is, instructional materials—among them. As a result, most instructional materials will be locally produced for local use; instructional computer use will remain a "cottage industry" with little cumulation, few incentives for authors, duplication of effort, and wide disparities among campuses in their access to effective instructional computer uses.

Decentralized Campus Facility

The decentralized campus facility has ordinarily been considered a less satisfactory situation than the centralized facility. It adds intracampus variations among computer facilities to the problems of intercampus differences. However, if the previously noted trend towards small, cheap computers continues to develop, this situation may change; for there are several reasons to expect such small computers to become standardized to a degree that their larger antecedents have not been. First, they are less likely to have associated staffs of computer scientists and professional programmers who know how to introduce local variations into hardware and software. Second, they are likely to be produced in a volume and by technologies that will favor standardization. Third, they will need a repertoire of prepared programs available on a standardized cassette (or other exchangeable medium) to serve the non-specialist users who will necessarily make up most of the market. In other words, the small computer may become a kind of "intelligent record-player" serviced by a market in standardized cassette programs the way the conventional record-player is serviced by the market in stereo records and cassettes. Should this occur, then each campus might have many computers for instructional purposes distributed as television sets or tape players are now. Together they would constitute a significant market for instructional materials made available in tape cassettes. These small computers might also communicate via telephone lines with larger computers when special functions, like access to large data bases or extensive computations, are required. However, until mass-produced, standarized, cheap computers become available, decentralized facilities are probably not the best choice for a college interested in instructional uses.

Regional Network

The regional network is a third possibility. It has the obvious advantage of providing access for each member institution to facilities of a capability and cost beyond those available to it independently. An even more important advantage for instructional use is that it provides a mechanism for the intercampus distribution of instructional materials. Physics professors at several institutions, for example, can contribute to a common pool of programs and share, rather than duplicate, each other's work. While such regional networks thereby offer considerable advantage over centralized campus facilities, they have two drawbacks. First, there is as little standardization among network facilities as there is among single campus facilities. Thus, while exchange within a network is eased, exchange between networks remains difficult. Second, the networks, as nonprofit organizations, have not developed the extensive and vigorous sales and marketing activities needed to encourage the widespread development and use of computer-based instructional materials, nor can they easily acquire the funds to do so.

Commercial Time-Sharing Service

The fourth possibility is the commerical time-sharing service. A number of schools are already making use of such services to supplement local facilities. Ordinarily they are used as sources of "raw" computer power; that is, they serve users who write their own programs in a conventional programming language. Some services also provide a library of common computational programs. However, a recent innovation holds considerable potential for instructional use of such services. Several services now collect fees for the use of programs stored in their program libraries; part of that fee goes to the program author as a *royalty.* Thus, commerical time-sharing services provide the mechanism for marketing computer-based instructional materials (and, of course, other programmed services) and for financially rewarding their authors. They also solve two other problems: nationwide access and standardization. The larger services, for example, link computers at several places around the country through communication lines and connect users to whichever computer has available capacity or the desired stored program materials. Thus, each service may make its materials available to many campus users around the country. Conversely, each campus user may gain access through his local terminal to many different time-sharing services. As long as each service provides messages compatible with his terminal (and that is not generally a problem), the user of programmed instructional materials is oblivious to the type of computer and programming language serving him.

Conclusion

Thus, of the four possible ways to provide instructional computer service to the campus, two have special promise for promoting the widespread production and dissemination of instructional materials: small, cheap decentralized computers programmed via standardized cassette, and commercial time-sharing services with royalty-paying program libraries. While the former lies somewhat in the future, the latter is here, although not yet widely used for instructional purposes.

PROVISION OF INSTRUCTIONAL MATERIALS

How will those materials be provided? There are two problems: Who will produce the materials? Who will distribute them?

Current Situation

Let us look at the current situation. As noted earlier, it might be best characterized as cottage industry. Materials are locally produced and locally used. The wheel—or, rather, the harmonic oscillator—is reinvented many times on many campuses. Individual authors rarely employ or build upon the work of others; there is little cumulation of materials and techniques. What dissemination and exchange of information occurs is voluntary and episodic; it relies on the enthusiasm and energy of both author and user, thus limiting the potential audience. A handful of national conferences, a small number of newsletters, and sections in several scientific journals constitute the extant communication system. The prospective user sees no salesman, receives no aid in putting the material into use. Moreover, the prospective author of computer-based instructional materials faces only disincentives. Since there is no commercial distribution, he anticipates no financial rewards. And since the materials are unlikely to reach his colleagues on other campuses, he is unlikely to reap professional prestige for his efforts. The administration is not even likely to reduce his teaching load or to reward him with promotion or tenure for his efforts. He would be better off writing a research paper or a textbook.

How might the situation be improved? Well, we have a model of a medium in which instructional materials are continually being produced and improved, in which cumulation of content and method occurs, in which there is widespread and effective dissemination, and in which strong incentives for authorship operate: the textbook.

The Textbook Model

The textbook is ordinarily produced by a faculty author, a practicing member of the subject discipline—often a respected scholar. His incentives are both financial (he stands a chance of doing very well on royalties) and professional (he can gain the stature and visibility in his discipline that provide both upward and sideward mobility). Others will be seeking the same rewards; thus there are likely to be a number of competing texts, offering different approaches and building upon previous texts.

Textbook distribution is in the hands, usually, of commercial publishers, who see that each text is appropriately designed and printed, who publicize the text, and who deploy a force of salesmen to make sure that each prospective user is aware of the text's strengths. They have strong incentives to see that the text is widely adopted and used.

Textbook selection is made by the faculty user who must choose among texts employing a multiplicity of approaches and content. Frequently, he chooses several texts. Often, he individualizes his course by adding his own locally printed materials. Sometimes, he becomes a text author himself.

Can this situation be matched for computer-based instructional materials? Can we create a situation in which instructional use of the computer advances through the cumulative contribution of the thousands of prospective authors whose energies are enlisted by a system that provides opportunity and incentives? We believe that we can, and that the two possibilities described earlier—commercial time-sharing systems and small, cheap computers—offer the means.

Commercial Time-Sharing Systems

Let's consider the commercial time-sharing system first. It might work like this:

Materials would be created by faculty authors (and student assistants or programmers) at many different campuses. Initially, these materials might be closely linked to existing texts; they might include problem sets, demonstrations, simulations, tutorials, and drills tied to text material.

Publishers would acquire the materials, edit and refine them, and place them into the program libraries of one or more commercial time-sharing services under a royalty payment arrangement. Each publisher would have a collection of programs in a given subject area stored in the program library. Thus, there might be the McGraw-Hill Economics Library, which would include tens of programs related to McGraw-Hill's economics textbooks.

The publisher's salesmen would demonstrate computer-based materials along with textbooks to the faculty members they visited on campus. A salesman might carry a portable computer terminal and leave it with the instructor to permit him to try each of the available materials.

The instructor could then choose from the program library those items he would like his students to use and arrange with the local time-sharing service for the installation of terminals (unless the school already had them) for their use. To further individualize the course he could develop some of his own materials and store them in the local service for his students' use as well. And once the terminals were on campus, they could be used to gain access to other publishers' materials: Wiley might have a competing economics program library, Van Nostrand might have one in physics, and so on.

Why would authors produce materials? Well, first, with widespread access, royalty payments could become quite significant. Second, the materials would be signed and their wide distribution could gain for their authors the reputation that translates into professional advancement. And, third, as the use of such materials grows, their development and refinement will become an inherent part of the teaching process, as the production of class notes and textbooks is now.

Three further aspects of this possibility deserve exploration. The first is, How will instructional use of the computer grow—institution-by-institution or discipline-by-discipline? Numerous attempts have been made to introduce widespread use of an instructional technology on a single campus. Most have failed to have significant effect. The University of California Irvine campus, for example, began with ambitious objectives in instructional computer use. The achievements have fallen far short of the ambition. A major reason, it seems to us, is failure to recognize that the college or university instructor shapes his course's content and method on the basis of what is considered appropriate by his discipline colleagues on other campuses far more than on the basis of what is being done by his institutional collegues on the same campus. Thus, the appropriate unit of instructional innovation is the discipline. Widespread introduction of the computer into instructional use will require the active participation of each of the major disciplines. In some disciplines such participation is already occurring. The Commission on College Physics has been active in development of computer uses in physics; groups in chemistry, engineering, and business administration have also engaged in information exchange activities. However, these efforts will have to be expanded in scope, in scale, and in coverage of the disciplines and linked more closely to "publishers" if they are to bring about widespread change.

The second is, Can a truly competitive market develop? Once a sufficient scale of use occurs, there should be little trouble attracting sufficient authorship to insure up-to-date, continually improving materials. The returns from royalties will likely be as great as or greater than those that reward textbook authors. Nor is copyright or patent protection likely to be a problem. The materials can be stored in a time-sharing system in such a way that access to their use can be gained, but not to the programs themselves—except at very great difficulty. Moreover, the creativity and rate of change are likely to be so great in the early years of use, as authors learn how to exploit the medium effectively, that copyright or patent protection would be of little use.

The third is, Who pays for the instructional use of the computer? Even when questions of cost and effectiveness are answered favorably, instructional computer use faces another, more subtle difficulty. It would be logical to expect the charges for instructional uses of the computer to come from the instructional budgets of the various academic departments. Yet how many department chairmen are likely to spend that budget on computer use, no matter how effective, in preference to faculty salaries? A fellow faculty member, after all, not only teaches, but does research, counsels students, and participates in the social life of the department. It is a rare chairman or dean who, given the choice, would opt for the machine instead of the man, even if the latter were less effective. As long as instructional computer use must be supported from departmentally allocated instructional budgets, it is not likely to gain widespread acceptance. It is instructive in this connection to note that in the case of the only instructional technology to gain widespread acceptance and use—the textbook—it is the student who normally pays. We expect that some similar arrangement may develop in the case of computer use as well. In that regard, the second of the promising alternatives—the cassette-programmed minicomputer—has some advantages.

Small Computers

The institutions for creating and producing instructional materials for the small computer system would be similar to those for the system based on centralized time-shared computers. However, each campus would have a number of standardized minicomputers into which instructional programs on cassettes would be inserted. The cassettes would be sold or rented—to students—in the same way books or records are now sold through local stores. Thus, distribution would be via cassette instead of via telephone access to a central program storage. However, we can imagine that the computers themselves would be paid for by the college or university, as a capital expense and not from department funds, and the students would bear the expense only of the instructional materials. Similar division of costs between institution and student are technically possible in the centralized time-shared computer case, but various practical difficulties make it seem less likely to occur.

EFFECTS ON HIGHER EDUCATION

Now we can turn to the last question: How would these developments affect higher education? Will instruction with the computer grow rapidly and revolutionize college teaching? Will it play a part in all courses and disciplines or will it be limited to a specialized part of the curriculum? Will its influence expand beyond the campus? Our study has led us to believe that the effects on higher education will be gradual, evolutionary, cumulative, supplementary, subsidiary, and paced by computer developments off-campus. Let me explain.

The computer's effect on instruction will be evolutionary, not revolutionary. Revolution will not occur because we do not now know enough, and we are not likely to be able to learn enough soon, to develop sufficient, effective instructional materials to change traditional practice in more than a very few courses. This will be true even if computer costs plummet rapidly. In addition, revolution through computer use would require considerable change in the organization and staffing of existing higher education institutions; that is not likely to occur short of revolutionary changes in the administration, sociology, and financing of higher education.* However, if a viable, national market for instructional materials is created, the chance of a gradual, evolutionary growth of instructional computer uses occurring is good. In the beginning, materials will be created for those sections of those courses for which the possibilities and techniques are most evident and in which the faculty interest is likely to be greatest. Problem sets, laboratory simulations, games, demonstrations, and drill for physics, statistics, chemistry, engineering, business, and foreign languages are promising candidates. As use of such materials spreads, as the incentives and opportunities for authorship grow, and as creative instructors across the country get the chance to experiment with computer tools, we have little doubt that many additional types of use and many uses in additional subjects will develop. As these materials cumulate, opportunities will arise to join them together in larger and larger segments. Finally, after a number of years, enough material and experience will have come together to enable computer-based courses to be created in a wide range of subjects. At that point, complementary changes in institutional structure and program will become desirable and feasible. The revolution will have evolved.

The computer's best chance for early advantage is in those parts of the curriculum that are in one way or another subsidiary, those parts that the faculty does not like to teach. For example, a reasonable market could develop in foreign language training for those who must meet doctoral or other requirements. Other possibilities exist in statistics for social scientists, computer programming, remedial subjects, and so on. In the courses of major interest, the computer's use is likely to be supplementary—that is, it will add to the quality (and cost) of the course, rather than substitute for some other means of instruction. In fact, we do not see great opportunities for cost savings until the evolution noted above occurs and changes in the structure and staffing of higher education can take place.

Instructional use of the computer may advance more rapidly outside of the campus than on it. The same computer technologies available to the campus—centralized time-shared computers and minicomputers—will be available to business and, not unlikely, to individual homes. The institutional constraints on instructional uses in such environments will be less than those on the campus. It is possible, therefore, that development of computer-based instruction will take place most rapidly outside of higher education and that the campus will be in the position of responding to those developments.

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* Some would argue that these are in the process of occurring (independently of the computer). Those changes that are taking place, however, do not seem to be making it easier for computer use to grow; quite the contrary.

RECOMMENDATIONS

Where do these findings lead us? What recommendations for action by higher education, industry, and government do we have? Recall that we argued that the objectives of national policy concerning instruction with the computer should be:

- To see that access to the computer is possible wherever its use would be cost-effective.
- To see that its use is refined and improved so as to broaden the range of circumstances in which it can improve instruction.

The study has led us to feel that these objectives will be best achieved by creating a market for computer-based instructional materials through actions that take advantage of opportunities presented by new developments in computer technology. Thus, the following recommendations are aimed at the creation of such a market.

Government

The Federal government should:

- Support R&D on hardware and software of special importance for instructional uses, including:
    1. *Terminals* that are inexpensive, easy to use, durable, and reliable;
    2. *Small computers* that can be programmed via a standardized, exchangeable medium and can be used with an inexpensive terminal;
    3. *Communications* among computers and between computers and terminals that are inexpensive and reliable;
    4. *Software* that makes more of the computer's flexibility as a medium available to author and user.

- Support the start-up phase of instructional materials development within discipline-based groupings. These should be a part of wider activities to develop materials using other media as well, and should include realistic plans for dissemination beyond the local facilities. They should be designed to become self-sustaining as use of the materials grows.
- Continue to support experiments in various ways to provide computer service and instructional materials to campuses, with special attention to the latter and to the gathering of careful, comparable cost and effectiveness data. Commercial time-sharing services and small computers should be two of the models tried and the discipline-based materials development efforts should be linked to those experiments when possible.
- Congress and the regulatory agencies should pay special attention to the needs of instructional uses of the computer (and to the need to create a viable market for instructional materials) when considering copyright and patent laws and regulation of the communications industry.

Industry

The several branches of industry having a potential interest in instructional uses of the computer should, first, pay far greater attention than they currently do to the potential of the educational market and, second, recognize that the instructional market is a market for materials (not raw computer power) and must be treated differently from the research or administrative market in education. Like the LP record market, both the equipment and the materials producers have a self-interest in standardization, interchangeability, and the volume and variety of materials provided by a multiplicity of producers. They should vigorously invest in the development of instructional uses of the computer.

The *hardware manufacturers* should focus their efforts on providing the standardized, reliable, and inexpensive hardware on which the materials will be used and on developing the operating systems and languages that will make the computer's flexibility available to authors and users. Hardware needs are greatest in terminals, small computers with exchangeable media, and communications facilities.

The *time-sharing services* should seek to develop the potential of the instuctional market by:

- Making special contracting arrangements with higher educational institutions that take advantage of the nature of such uses to lower costs;
- Developing the hardware and software facilities to build, maintain, and use large libraries of instructional materials on a fee-for-use basis;
- Cooperating with publishers and faculty authors to build libraries of instructional materials;
- Seeking terminal and communications compatibility with other time-sharing firms so that the campus user will be able to use a multiplicity of sources.

The *publishers* should concentrate on developing the means for facilitating authorship, for editing and refining the author's initial product, for distributing programs, and for marketing. Initially they should concentrate on a wide variety of supplementary materials (relating to existing texts) for subjects such as physics, business, economics, engineering, statistics, and chemistry. They should cooperate with a variety of time-sharing services and small computer manufacturers until the market settles down. They should engage respected men in the disciplines in the production and selection of materials through cooperation with discipline-based commissions and through formation of editorial advisory boards.

Higher Education

The two groups to whom recommendations are appropriate are the administration and the faculty.

Administrators should seek to create an environment in which the computer's potential to assist in the instructional process can be explored free from extraneous impediments and subject to positive support. Among the steps that can be taken are:

- Encouragement of faculty participation in experiments with and development of computer uses by providing teaching time to develop materials and promotion rewards for those who succeed;
- Encouragement of cooperative efforts with other institutions in which instructional materials are shared;

- Selection of modes of computer service for instructional purposes that facilitate the sharing of instructional materials with other institutions;
- Setting aside a portion of the budget for support of development of computer materials that will be
    1. Subject to careful cost and effectiveness evaluations,
    2. Designed for use on other campuses,
    3. Feasible and acceptable for use on the local campus.

Faculty should seek to develop effective uses of the computer to improve instruction that

- Are suitable for more than local use;
- Make full and imaginative use of the computer's capacity;
- Draw upon the skills and experience of other faculty in the same and related disciplines.

To this end, faculty within a discipline should encourage the formation of groups to develop instructional materials jointly.

SECTION THREE

Workshop Recommendations
Dinner Speech
Contributed Papers

Workshop A:

RECOMMENDATIONS FOR INSTITUTIONS OF HIGHER EDUCATION

The workshop was attended by 18 people, all of whom made specific and significant contributions to the results. Major concerns were solicited from each participant and then as many consensus-supported recommendations as possible were shaped in the time available. Four general recommendations are presented below, followed by the list of solicited concerns.

1. Institutions, in particular their policy-makers and top administrators, should study and take a clear stand on the recommendations of the *Commission on Instructional Technology.* They should also study and take stands on various other reports bearing on the area of instuctional improvement. The recommended stands should be made public with the intention of affecting the Congress, directly and through the electorate. Enacting legislation is now before the Congress. Now is the time for institutions to make their positions known and to work for the results that they want. The purpose of this recommendation is to assure that the Federal establishment and the Congress move toward the most desirable solution.
2. Institutions, and particularly their administrators, should deliberately take leadership by finding ways to identify people and to stimulate them to solve the problems of harnessing technology to the improvement of instruction. This leadership initiative should be guided by each institution's own point of view, and the efforts should be conducted in each institution's own self-interests. The purpose of this recommendation is to assure that institutions will not abdicate their responsibility for leadership in the face of Federal establishment initiative. To the extent that technology will provide major new resources for instruction, institutions must assert themselves to guide the development of these resources into becoming supportive of institutional goals.
3. Institutions should not endeavor to add to the inventory of technology for application to the problems of improving instruction without clear specifications of need; and where a need is clearly specified, reinvention should be diligently avoided. The purpose of this recommendation is to persuade

institutions to *pull* technology into instruction in response to *need*, rather than permit technology to be *pushed* into instruction in response to its *existence*. Much technology is available now; more is being generated at a rapid rate. It is hard to imagine what else is needed with any precision. On the other hand, the shortage of problem-solving resources demands that a strategy of *need/pull* be used in place of the current default strategy of *existence/push*.

4. Institutions should reopen the question of institutional goals in the light of the large potential impact of technology on instruction and the expected high cost of incorporating technology into instructional processes. The purpose of this recommendation is to avoid the real costs and the opportunity costs of attaining the wrong goals.

These four recommendations are complementary, and together they recommend that institutions get involved in specific ways for specific reasons. The workshop found that a general admonition to "get involved" would not be useful, so these recommendations attempt to delineate the most important things to be done.

MAJOR CONCERNS

To identify the area of policy concern, the participants all contributed their most urgent and important issues for consideration. These issues are detailed below, after being grouped to form coherent clusters. The original wording is preserved as much as possible in order to transmit the original ideas.

- *Get involved.* Involve students, faculty, administrators, and the general community. This implies restructuring the incentives to foster innovative *need/pulling* of technology into the instructional processes. At the same time, simplistic models of involvement should be avoided.
- *Cater to the market.* Reach out to the community; pay careful attention to the relevant constituencies; be sure to develop and deliver a good product.
- *Consider the recommendations of others.* Specifically, consider those of the Commission on Instructional Technology, and others.
- *Funding, budgets, and allocation of resources.* Recognize the needs of areas that are new to computing and of students enrolled in courses not specifically using computers. Install a promoter of instructional innovation, a monitor of progress, and an evaluator of instructional improvement; give each of these a budget that is independent of the traditional departments or other budgetary units. Specifically allocate money for research on learning, teaching, and instruction.
- *Don't reinvent technology.* Use the work of others; report work in such a way that others can use it; use commercially available general-purpose equipment for experimental developments rather than devising special-purpose equipment that cannot be replicated elsewhere.
- *Reopen the question of institutional goals.* Avoid spending large sums on attainment of the wrong goals.
- *Integrate technology.* Pull together the technology required to solve the

problems in hand; avoid using technology just because it exists. Spend extra effort to be sure the problems are clearly identified and articulated.

- *Organize additional communication and distribution mechanisms.* Organize such mechanisms by discipline, after the fashion of the Commission on College Physics; create more means for distribution of ideas and results for improvement of instruction; create other kinds of mechanisms as other sensible ideas arise.

Workshop B:
RECOMMENDATIONS FOR INDUSTRY

1. There is a need for *turnkey commercial suppliers* of service for the instructional use of the computer, including hardware, system software, and instructional materials. Companies now supplying specific products or services (such as publishers or time-sharing services) should look toward providing total packages.
2. Industry can accelerate the development of the market by giving more financial support to the *development* of high-quality computer-related instructional materials. In addition to the traditional form of supplying risk capital for a specific project (such as a royalty advance to an author), industry should consider *joint efforts* to support the development, testing, and evaluation of instructional materials.
3. Large corporations can use their *in-house training programs* as test markets for the use of the computer in instruction. Industry-run "proprietary schools" (e.g., trade schools, adult schools) also can be used to develop, test, and evaluate computer-related instructional materials.
4. Industry should pay increased attention to promoting *compatibility* of both hardware and software. Cheap, programmable interfaces could obviate the need for strict standardization. *Documentation of software at all levels must be improved.*
5. The several industry associations concerned should take the lead in establishing satisfactory *royalty* arrangements for authors of computer-related instructional materials.
6. People from industry, at both the management and working levels, should become more intimately involved with campus use of the computer for instruction. This can take many forms, from visits of a few days to full year sabbaticals. The objective is to focus industry's attention on the real opportunities and problems associated with instructional uses of the computer, rather than on higher education as simply another market for standard products and services.
7. Industry should recognize a need and a present market opportunity to improve the *administrative* uses of the computer in higher education.

Workshop C:
RECOMMENDATIONS FOR GOVERNMENT

The workshop concentrated on the prospective role of the Federal government in the development of instructional uses of the computer. The workshop saw the role of the government as one of funding R&D, encouraging national planning for the development and use of instructional technology, and supporting demonstrations of such technology. It urged that the state legislatures recognize the important role of computing in state institutions of higher education and provide adequate support for it.

Three major recommendations were made:

1. A coherent, continuing national R&D program in instructional uses of the computer should be sponsored by the Federal government. The program should link the efforts of the several Federal agencies who support such activities. To organize and manage this program, the proposed National Institute of Education should be authorized and funded.
2. In order to design an appropriate R&D program and to guide decision-makers in government, industry, and higher education, the Federal government should support the evolutionary development of successive generations of *draft* functional requirements for instructional uses of the computer. These requirements would be based on considerations of (1) the needs of society over 5 to 20 years and the urgencies and priorities within that society; (2) the needs of education with particular reference to the specific requirements of students, of course authors or instructors, and of educational administrators; and (3) the set of means available in the spectrum of current technology for meeting these needs. Since both the needs of society and the means within technology tend to change, evolutionary development in successive generations of dated drafts is essential. The function of these documents would be to provide a graphic target or a conceptual model from which it would be possible to (1) identify needed R&D; (2) characterize "worthwhile" operational implementation; and (3) furnish hardware and software design criteria for industry. It should be noted that the existence of such documents in draft form leaves open the possibility for disagreement but, at the same time, constrains the types and

level of criticism. Also, the existence of a target simultaneously furnishes the political incentive to reach it.

3. The Federal government should support a series of experimental and demonstration facilities in which instructional uses of the computer are tested and developed in actual educational settings, with adequate support, careful evaluation, and sufficient time. One place where demonstration computer systems might be successful is in providing personalized instruction and practice in English and mathematics for those who enter higher education with inadequate preparation.

COMPUTOPIA AND CYBERCRUD

Theodor H. Nelson
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Here I am again. I regularly cry in the wilderness at banquets, conferences, and other ceremonial events. I have been doing my thing for ten years, and giving these talks and publishing articles for five, with little result. My articles have apparently been boycotted by *Computing Reviews*. I seem to be the Electronic Eeyore.*

The truth is that I am not really trying to interest computer people. They are the ones who only seem to tell me, "It can't be done." There turns out to be no answer to that. Many times I have come up with a way to do something, in which case the man who said it couldn't be done usually says, "Why would you want to do such a thing, anyway?"

It is the laymen and literati, the noncomputer people, I want to reach. But this also seems futile. A few laymen and literati occasionally seem to become quite turned on; but without Experts to confirm what I say is possible, they gradually edge away and don't listen either. I feel like Marco Polo in his later years, no longer Italian and certainly not Chinese, trying to interest one in the other.

I am here again to say what I always say, not so much to influence anybody now as to say "I told you so" later. I would rather say what I think, and seem to be a lunatic, than try to make a favorable impression by lying about my true opinions. This way also I can treat you to a shock of recognition several years hence, when you say to yourself, "Oops—that was the prediction."

In 1966 I spoke at Rand, also under Roger Levien's sponsorship. The 1966 talk, "Hard and Fast Thoughts for a Softcopy World," is perhaps interesting in several respects. I made a number of crazy predictions. They seem less crazy now, and various of them have come true already. I have nothing to retract and relatively little new to say, except for a few details.

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*See especially "A File Structure for the Complex, the Changing, and the Indeterminate," *Proc. ACM 1965;* and "Getting It Out of Our System," in Schechter (ed.), *Information Retrieval: A Critical Review*, Thompson, 1967. The tale is poignantly told in "Barnum-Tronics," *Swarthmore College Bulletin* (Alumni Issue), December, 1970.

What Roger has asked me to talk about again tonight is "the computer as a medium." But that doesn't quite put it my way. I see the computer as the heart of the new presentational systems of the future—and this vision seems curiously different from what we generally hear. What we must work on are the principles of presentation, not of computers or other technology.

We are usually told, on various sides, that some kind of revolution of human information is upon us, but somehow in the course of things the computer will make this revolution inhuman. Chugga-chugga, we will have to learn obtuse query languages. Rattle-clank, we will get answers back in symbolic logic. (Too bad for some of us.) Tippity-tap, the terminal will tell us a thing and then ask us what it told us. Tell and test, tell and test, instant boredom, but who dares argue with science?

The title of my talk is a slanted dichotomy: "Computopia and Cybercrud." However, these terms may need a little elucidation.

"Computopia" is of course a portmanteau of "computer utopia." Each of us in computers has (or should have) his own computer utopia, some vision of a future better world in which the computer figures prominently.

Unfortunately, there are many trivial horizons being offered the world by computer people: shallow possibilities, uninformed aspirations. I refer not only to commercial enthusiasms—one sees published articles with titles like "New Horizons in On-Line Credit Reporting"—but also to cramped visions of the ideal. Cramped visions are all too common; but the worst thing is that here they are contagious. They are sold to the public as technically necessary, and the public doesn't know any better. This is the cybercrud problem: advice and creation of systems, supposedly based on technical requirements, whose categories and rigidities are unnecessary. In the worst cases they are not only unnecessary but wrong.

If the public doesn't know what is technically possible, you can sell them any inflexible kludge and tell them it has to be that way. Unfortunately, technically sophisticated people forget how uninformed and timorous about such matters the rest of the world is.

Once I was surveying individual departments in a big company, having been assigned to find out if any new technologies could be used in the work at hand. Now, I couldn't just ask, "How could technology help you if you knew more about it?," since that's like asking, "What fact that you don't know is the most important?" So I developed a little song-and-dance for the purpose. "Suppose," I said, "that anything was technologically possible. Suppose it's the year 2000." (This premise was the tongue-loosener. Somehow the year was sufficiently unimaginable, or the sense of having to be answerable for the consequences could be suspended.) "Suppose technology could give you anything you asked for," I said. "What could your department use?"

The interesting thing I learned was that when you asked mature people in business what they might want in the year 2000, they almost invariably (a) wanted computers to take dictation, but otherwise (b) came up with things which were presently possible, though perhaps expensive or awkward. But one reply I will never forget came from a lady in charge of a language teaching program. "I suppose that by the year 2000," she mused, "each child could have his own tape recorder."

The horizons I am talking about lie a little further. Within the coming decade we will see the explosive growth of computer display, an expansion that will rival or surpass that of television, and compare in ubiquity to the very telephone. We are going to have an entire cultural revolution based on computer display.

It is my belief that many important benefits can flow from this revolution, if we do it right. I believe enlightenment, knowledge, and understanding can be furthered throughout the public. I believe creativity can be fostered in many of its forms. And I believe a new and important freedom of information is possible.

This is my prediction and my call to battle; evidently few of the most ardent enthusiasts of computer display go so far. But if it is correct, it means a revolution in human life and thought comparable to what followed Gutenberg. My interest is in giving shape to that revolution, in urging it toward enlightenment and humanist freedoms, rather than having it stumble accidentally into the formalization of dreariness.

There is no overall term for what I am talking about. "Information retrieval" and "computer-assisted instruction," with their false ring of exactitude, say less than they seem to. "Computer display" is a technology. But I would like to propose a term for what I am talking about: *fantics,* the art and technology (in that order) of showing things.* The major precepts of such a field should be to make things look good, feel right, and come across clearly. The use of screens and computers is indicated.

What will these screens be for? And what will be on them? Many people seem to be in the grip of the travel-agent idea—that screen terminals will be for bank clerks and airline reservation people. Sure, for a while. But they are also going to be in the home. (And if we have them in the home, they may not be needed by travel agents.)

I want a world where we can read the world's literature from screens rather than personally searching out the physical books. A world without routine paperwork, because all copying operations take place automatically and formalized transactions occur through formalized ceremonies at consoles. A world where we can learn, study, create, and share our creations without having privately to schlepp and physically safeguard them. There is a familiar, all-embracing motto, the jingle we all know from the day school lets out, which I take quite seriously: "No more pencils; no more books; no more teachers' dirty looks." The Fantic Age.

If you asked me what my computopia is, then, I would say a sort of Woodstock with terminals. With terminals on all sides, we can more easily go barefoot and pocketless. I propose to turn on people's minds with display screens rather than drugs.

Those of you who have moved your possessions and papers while switching universities are aware of the burden on the individual of retaining documents and records in paper form. This weight off our shoulders will be a pleasant side benefit. But I see two greater steps we will be taking. Our screen-and-computer systems will help us in the difficulties of organizing thought, of revising writings, of indexing complexities. And when our works are finished, we will send them out on screens —marvelous new forms of writing and illustration.

In dark contrast to such a possible enlightenment, I would like to point out an

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*The term, etymologically impeccable, is from the Greek *fanein,* to show. The pleasing connotations of "fantasy," "fancy," and "fantastic" are fringe benefits.

unfortunate tendency, occasionally a villainous practice, which we may call *cybercrud*. By *cybercrud* I mean putting things over on people using computers.*

Cybercrud can take many forms, all related. The computer's cachet may be used to hide your premises, the way you want to do things, the secret loadings of your approach and procedures. The computer, its accessories, and terminology, can give the semblance of validity to all sorts of procedures or statistics. The term "computer" is to many a rubber stamp meaning "scientific."

We may use the computer, or the mention of it, to perplex, intimidate, or bamboozle. This, too, is cybercrud. The following subscription renewal letter has a certain charm.

> Dear Subscriber:
>
> Because [our] . . . subscription roll is maintained by electronic computer, it is necessary for us to assign a common expiration date to all subscriptions. This enables us to distribute copies and mail renewal notices to all subscribers at the same time. Therefore, we are writing to inform you that your . . . subscription must be renewed *now*. . . .

We may note that while this electronic computer requires all subscriptions to end at the same time, it nevertheless does not require all subscribers to live at the same house or have the same name.

Cybercrud is most surreptitious, even if benignly and sincerely, in the "one-way" form. This consists of presenting one's own way of doing things as *the* way, hiding the fact that it is one of many alternatives. Of course it is natural, in the throes of enthusiasm, to forget to mention alternatives, to present as scientific the consequences foisted by one's premises. "This is how the computer bakes a pie!" says the press release—and recipes are not compared.

With the public so flummoxed by computer news, and so easily taken in by breakthrough pronouncements, the mischief of this tendency is great. "You have to submit out of technical necessity" is the gist of this form of cybercrud. This is equally unfortunate when said by computer salesmen or by professionals prematurely set in their ways.

Of course, it is possible to believe sincerely that one's own way of doing things is the computer's way, the only way it can be done by computer. But we know that this is rarely if ever so. Actually the computer is a *tabula rasa*, a projective system, whose behavior takes on the preconceptions, and sometimes the personality, of those who set it up. But the possibilities can far exceed what given individuals think of. And this is the problem that brings us here tonight.

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*Since in the course of present-day technology promotion we find ourselves affronted with too many cruddy words beginning with "cyber-," I thought it was time to coin my own "cyber-" word, one that would be explicitly, rather than implicitly, cruddy.

The derivation of "cybercrud" is as weaselly as its meaning. To the general public, the word "cybernetic" means, rather incorrectly, "related to computers," whereas from a technical point of view it more exactly means "concerning control linkages." Thus the prefix "cyber-" has the proper connotation of "spuriously related to computers." The actual *Greek* "cyber-" meant "steersman." Thus at the micro-level we may think of "cybercrud" as meaning, "steering into crud, with spurious connotations of computerishness."

EDUCATION

That school is stupid, boring, and insulting need scarcely be mentioned, except that we tend to forget it. We forget the inanity, the complete nonsensicality of most grade school and high school pursuits. Their insignia of officiality somehow seems to make them right. What matter if children's good time is being wasted by astrology, candle-dipping, or Euclidean derivations? Any nonsense will do, so long as it leaves a trail of *grades*, evaluations etched in history that can be used to blackmail the victims or their parents.

Curricular timing and grading virtually obliterate the nature and natural interest of every subject. It is as though we were taken in groups to visit national parks in the back of a truck, racing on a treadmill. Every possible activity is related to a made-up standard; nothing is allowed to be merely interesting. For those on the up side, the system furnishes clues as to direction of reward; for those on the down side, the presumption of *own failure* is affixed to the subject. Few of us do not learn that we are "no good" at something, and adult regrets are heavy with both the realization that it could have been different and self-blame that it was not.

Some remarkable traditions govern the structuring of subjects as we teach them. But they are no more in the nature of the things to be learned than the cuts of steak are in the anatomy. Every subject has a beginning, a middle, and an end; it is laid out by the assigned reading and precisely bounded by the scope of the final exam; every topic may be reduced to shallow enumerations strung on vague explanatory connections, dismally explained inanities, explanations which associate phrases without a sense of meaning, and incompletely explained "skills" to be practiced without insight. Questions and other matters therefore become either "relevant" or "not relevant," according to whether they fit the boundaries and sequence of the "subject." And thus it can come about that the answer to a question is, "Just learn what you're told."

We have been misled into believing that all this is how it has to be: the cascade of premises flows into a landlocked swamp.

The idea of prerequisites and "basics" is one of the few justifications for having curricula at all. In a few clear cases—say, the differentiation of mathematical functions, or punctuating correctly—it is impossible to do the more complex detail work without having learned exactly to do the simple detail work. But I believe that such cases have grossly misled us. We suppose that because some learning sequences cannot be circumvented, then all learning should be reduced to sequences. This has several disastrous consequences.

First, unique curricular paths. The curricula of the schools are generally designed as pathways radiating from some primal state of ignorance, wagon-wheel spokes without the wheel. The only way to learn most things in school is by taking an exactly prescribed series of intermediate steps. There is no way around. And if one has not taken the steps between, a thing simply cannot be learned.

The psychological consequence is most pernicious. There are things one "knows" (if the details are forgotten, one is still oriented) and things one "does not know" (there has been no introduction, no orientation). A sense of weakness is produced; one drops a subject that has come up; one shrugs. But this is only part of it. What is much worse is that when one has "failed" in a subject, all further thoughts about this subject are darkened, colored by this sense of failure. One avoids;

one strives actively to find other interests or distractions: "Aw, never mind that stuff."

Last, the sociological consequence. We produce people with funneled minds, the so-called "types"—the literary type, the scientific type, the mathematical type. And an occupational structure around these types. And subcultural divisions. And everybody stays where he feels safe, and everything interesting in the world is hidden from almost everybody.

A lot of people I talk to say, "I don't think it's as bad as you say, but I agree that the educational system can be improved." But I'm not sure it *can* be improved. The system is geared and swivelled to do exactly what it does: discourage and mediocrify in the guise of sticking to business. It's not merely a question of whether real improvement is possible within the system, but also of whether it would still be the system if we made any real improvements. Imagine (if you can) people growing up without a self-stereotype of structured disabilities, who thought they could do anything if they worked at it. Imagine most people having a real choice of occupations. Imagine if the classroom atmosphere could be stripped away and the students put in genuine rapt communion with the subject—a state which teachers are sometimes deluded into thinking they achieve—without the deleterious effects of competition, time pressure, and stigmata for real participants. Imagine kids experiencing the excitement of intellectual issues—and not just as a fleeting part of that grim academic exercise, writing a paper. Imagine students actually interested in school. Or whatever we would now have to call it.

DESIGNED AND SIGNED WORKS IN COMPUTER MEDIA

Roger Levien says that the part of my 1966 talk he remembers is the discussion about "the computer as a medium." Let me go into that in some detail.

I said this: A number of new media will come about, employing computers or other digital means. The computers will store, respond, display, and follow complex directives about their response. What they show will consist of *works,* intentionally organized things whose impact on the viewer or participant has been designed, much like the parts of a picture, a book, or a movie.

By "media," then, I mean stabilized forms of presentation that people will create works in, for other people to use and enjoy. The presentation may be carried out by computers; but its plan, and the viewer's feelings, will be mediated by other human beings.

We have many media now: the newspaper, the movie, the phonograph record, the TV show, and many more, each with its own variations. We understand these media and the people who do things in them; we understand the position of the reporter and the columnist, the photo-journalist and the movie director, and their contributions in bringing us facts, impressions, and visions.

Yet for some reason we have failed to extend this understanding to the media that will be brought to us by the computer. There is a floating myth that computer media will be different from all those that have gone before, either thrown together on the fly by the machine itself, or presenting passive nonedited descriptions of the world, or dutifully constructed on scientific principles by psychologists who remain aloof from the content. I find all of these ideas rather absurd, especially since to formulate them we ignore our extensive experience with other media.

If the computer itself puts together presentations for us, it is acting not as a medium but as a facility, according to rules we will wish to control. (Even if it presents a montage or pastiche, the locus of action is still not the computer, but the formula for what the computer is doing.)

The second view is that the computer and display will merely dip into some data collection which passively describes the world. One new machine, the Evans and Sutherland LDS-1, dips into a three-dimensional data structure, much as a goldfish net is dunked to surround guppies. The user may roam and wheel through whatever world is represented in core memory, with almost no programming needed. Such systems might leave one thinking of the material to be shown as simply a view of the world, a neutral representation or assortment, to be routinely prepared by anonymous coders. (Simply to describe it this way shows the suspiciousness of this view.)

The third possibility is a view that there are neutral or colorless scientific methods for organizing presentations, especially those methods growing out of learning theory. This seems to me like saying that since photography is optical, photographers should be trained in optometry, or that record producers need to study psychoacoustics. It is not necessarily relevant to what should be done or what the media are going to be about. If the principal impact of a teaching system is a matter of feelings, appeal, and cognitive handles, as I believe, then *these* are where we must place the emphasis.

But this is the general view in "computer-assisted instruction." That instruction must be the presentation of sequenced chunks and questions in a conversational format seems to have become a fold premise, generally blotting out other possibilities of computer teaching. At best, computer-assisted instruction can be very good indeed, in which case the only possible criticism is of the immense cost of preparing materials. But at worst, it seems to be a conspiracy to do some of the worst things school has ever done: cut and dry the material, spoon-feed, bore, and insult the participant.

I think none of these models represents the main thing that will happen. Rather, people will be designing display-based media and creating works in these media. Indeed, people will be signing them, just as ever before, and viewers will seek out the works of particular authors much as we do now in every other medium.

We have gotten to my position and main interest. I believe the computer's astonishing possibilies as an aid to the human mind and imagination have scarcely been touched, and the new media made possible by the computer and display will be miraculous and awesome.

I have suggested using the prefix *hyper-* in general for multi-dimensional and nonsequential computer media, those having some kind of complex order within which the user may roam.

Since computers can control any other equipment, we may expect new media which tie together old forms of presentation in new ways; for instance, the branching motion picture (hyperfilm), or branching audio. But I suspect that all these hybrid systems will be comparatively unwieldy—the expense of branchable film transport systems, for instance, is immense compared to all-digital systems—and interest will converge rather soon on the pure digital media for the computer's own display: the hypertext and hypergram.

PRESTIDIGITATIVE PUBLISHING

To supply our scopes with the hypermedia we will want to read, I foresee a new era of publishing, and a whole new publishing industry. In this coming era the digital files of the publisher will be connected by telephone (or other means) to the subscriber's console. As you ramble through hypertexts or explore hypergrams, the news of your actions will be flashed to the great feeder machines at the publishers' distribution centers. These feeder machines will disgorge to the customer the furtherances of what he is doing, keeping him continuously supplied. The material will be copyrighted, and small royalties will be continuously billed for screen-minutes of presentation. Entirely new creations and the works of the past will be equally and quickly available. Enchanted gardens of information, prearranged by authors and editors, will be available to you. Screen pyrotechnics and display tricks will be intertwined with pictures and text. There will be anthologies, magazines, encyclopedias—or things like them.

A related development will be *creative facilities,* systems for using computer displays to help in creative activity. Publishers will serve as storage warehouses for the overflow from such systems, and probably buffer materials and messages being sent privately among users.

The user will be able to perform input and complex parallel annotation, keep a trail of his own activities, and backtrack through his own past actions and those of others. In other words, Vannevar Bush's "memex" will come about substantially as he saw it."*

STRETCHING THE IMAGINATION

An important human tendency is to rationalize and order what we hear. I have found that people at my lectures continually assimilate what I say about hypermedia to some pulsating "new world of communication" they have heard about, mushing together computer-assisted instruction, information retrieval, holography, and even cartridge TV.

I often talk about stretchtext, not because I am so attached to it, but because listeners who understand the concept cannot continue to believe I am talking about the usual stuff.

"Stretchtext" is a form of hypertext I have suggested for discursive written subjects, such as history and the social sciences. In stretchtext, the reader may control the amount of detail to suit himself; as he pulls on a throttle or some other control, additional words and phrases appear on the screen, and the rest move apart to make way; as he pushes the throttle in the other direction, words and phrases disappear, and the rest of the text slides back together.

The presentation should never change sharply. Smooth motion of the text pieces on the screen is utterly essential. For instance, a long sentence should, as expansion continues, be broken into two short sentences as similar to their parent as possible.

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*The particularities of this prediction are pursued in my article "As We Will Think," presented at the September 1968 meeting of The American Chemical Society; to be published.

Although we have as yet no firm evidence, my slight experience trying to write stretchtext suggests that it is no harder to write, and perhaps easier, than ordinary prose. To each small piece of text is assigned an *altitude*, or "degree of stretch," at which it is to come and go. The problem is basically to lay out an overall expository structure and then find some way to compress it gradually without large jumps or reversals of sequence.

Discrete hypertexts and hypergrams are essential and basic. Simply put, these are writings and pictures with footnotes that extend in all directions. Touch an asterisk, or perform some equivalent act, and the system will bring another connected thing to the screen.

More complex hypergrams are very desirable, particularly those capable of immediate and smooth response on the screen. Consider, for example, a map on your screen which you may move around the world and zoom in on any part, to any degree. Look at the whole United States and zoom in on Secaucus, New Jersey, and environs. By various manipulations the user should be able to overlay this picture with populations, climate, historical events, light industry, or crime statistics.

Consider another hypergram: a picture of the human brain which the user may actually manipulate in three dimensions. (This is a particularly interesting example because of the stereoscopic complexity of the brain.) The user should be able to rotate, magnify, zoom in, change perspective and viewing angle, brighten different subsystems, and obtain annotations.

Finally, consider a cartoon human body on the screen, having various simple animations (heartbeat, peristalsis, etc.) and permitting the user to open it up in various ways and views, as well as get labels, explanations, and other annotations.

It will be noted that in none of these media have I made any reference to sequence. Thus it will be plain that these activities are not the same as the prescribed-sequence formal activities being pursued generally under the name of "computer-assisted instruction."

Finally, it may be divined that these systems overlap in function with both "information retrieval" and "computer-assisted instruction." I am persuaded that neither discipline, in its larger sense, can or should have a separate existence. "Information retrieval," unless it deals with the simplest facts, must also involve orientation and learning materials. And, as I have already pointed out, systems intended for teaching will need to open up whole new areas of option, until they become very, very like hypertext.

INTENTIONS AND PRIORITIES

The next question in your minds may be, "Where does all this lead?" If instructional sequences are not the right place to put our effort, what sort of things do we do next?

There are two answers. On the one hand, we should be trying out new organizations of information, grand complexes of words and pictures that the user can peruse, explore, and learn from. Unfortunately, present presentational systems are very badly suited to this purpose. Conventional computer systems are designed with other things in mind, and I am increasingly convinced that some rather basic changes are needed before proper environments are available.

Speaking for my own aspirations, and those of The Nelson Organization, Inc., with which I am coextensive, I believe one of the best possible contributions to civilization would be the creation of new media to be digitally stored and interactively studied. It is our hope to become the fountainhead of these new forms of writing, reading, teaching, and the ordering of thought, and to offer materials to people with appropriate consoles within a few years. By copyright and authorial credit we hope to establish a position both as a supplier and as a place for talented people who want to create the new works.

These people will not be technicians or psychologists. They can have been writers, artists, movie-makers, the "creative people" of advertising, editors, photographers, museum people. They will be people who enjoy creative construction and who have a special sense of visualization, space, word and picture; and (I would guess) people who have loved at least one responding machine, be it bicycle, camera, typewriter, or automobile.

Why not computer people? Because in one sense the computer part is the easiest. They used to say at *Life* magazine, in the old days anyway, that a photographer could be taught to write much more easily than a writer could be taught to take pictures. I think that the same obtains here: the writers and artists can probably absorb most of what they need to know about computers for hypermedia in a short time. A few may eventually get into system design and tradeoff, but I expect the basic forms of CRT hypermedia to stabilize rapidly.

But for the present not much can be done. There is no point in creating these materials now, and without proper systems it is far too much trouble. It is fun to design hypertexts in a vacuum, but not very much. The difference between trying to imagine it working and having it do so is roughly like the difference between a bearskin rug and a bear. Designing hypertexts without a proper system is rather like preparing magazine pasteups before printing presses were invented. It only gives you more designs to have to explain to people who will call them vague conjecture.

Before these materials can be created and distributed, we need people to have sufficiently opulent systems. Using the LDS-1, Evans and Sutherland have demonstrated the sort of zoom-in hypermap I spoke of. But an Evans and Sutherland display setup is a matter of half a million dollars or more, and hardware at this level of investment is not worth talking about for teaching anybody anything, except perhaps how to get appropriations for computers. Similarly, the Brown University Hypertext Editing System, which I had a hand in,* permits the comfortable creation and reading of discrete hypertexts. But for that you need an IBM 360 with 2250 mod 2 display console, another immense outlay, so that too is not practical.

For all intents and purposes of The Nelson Organization, Inc., it is necessary to have wonderful consoles. And this is therefore the current thrust of our Project Xanadu: to put mountains under our castles in the air.

Naturally, this cannot all be done at once.

The prototype, which we hope to build in 1970-71, could not practicably be sold for under a hundred thousand dollars. But we have in mind, building on this, a commercial system a few years away whose price is more like ten thousand dollars, including all software for CRT hypermedia, and including CRT, screen, keyboard, dashboard, tablet, disk, and communicator. This would require, however, a whole

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*Gross, Carmody, Nelson, Rice and van Dam, "A Hypertext Editing System for the 360," *Proceedings of the Second Annual Conference on Computer Graphics,* University of Illinois, 1969.

new approach, utilizing through-designed hardware and system programs. I will shortly talk about some of the approaches we are looking at.

DESIDERATA

Keyscopes, or text display consoles, are not yet what they should be. While the more attractive units, such as the Datapoint 3300, are now comfortable and attractive enough for long hours of use, they are not yet sufficiently zingy for the hypertexts we are going to want. The most important feature such text consoles will need, in my view, is some capability for smooth text motion. Only if you can see where a piece of text is coming from, and which way it goes, can your eye and mind remain oriented. (Unless the display space is trivial, say, one made up of "pages," or long scrolls.) Moreover, variable-sized characters, italics, other fonts, and serifs are all desirable, in that order.

It is possible that keyscope terminals, such as the TV raster-chopping type, might be improved along these lines, but the engineering might be difficult (and the engineers unmotivated). For these reasons I put my hope in calligraphic systems—those which draw with a programmable beam of electrons, such as DEC's 338, IBM's 2250, the Adage terminal, the Vector General display, etc.

And for the general purposes of CRT hypermedia, even the best, excepting always the miraculous Evans and Sutherland machine, is not yet good enough. The finest calligraphic displays, such as the 225° and Adage terminals, are usually hampered by the big computers that support them. A sudden refusal to respond often means the main computer is stopping to print something or punch somebody's cards.

Some way has to be found out of this. The usual solution proposed is to have more and more immense computers doing the main work for the display. The solution I favor is to use the display's little computer better and use big computers less or not at all.

XANADU

The term "Xanadu" I have used since 1966 as an ongoing project name for the console I have wanted to build. The overall set of ideas and preferences has been churning in my head since 1960. Its functional specifications, frozen along with its name, now seem within reach. I called it "Xanadu" after the pleasure dome in the poem "Kubla Khan," with its connotations of mysticism and artistic trance, to say nothing of the cachet added by Orson Welles' appropriation of it as the name of Citizen Kane's palace.

Here was the idea of it:

1. It was to be created for the naive, antinumerical, and accident-prone user. There were to be no visible numbers, save those explicitly put in by the user. Unintended actions by the user could not harm his files or undo his work, because of several levels of backup, fail-safe, and warning. (At the extreme, procedures of the utmost gravity would be required for dangerous and irreversible actions, similar to the protocol said to be established for the firing of intercontinental missiles. For

instance, for the user to throw a thing away completely, expunging all copies of it, he would really have to want to. Several stages of warning would occur, to be overridden by complex acts, culminating in a phased two-handed maneuver while a small hooter siren went woop-woop-woop, all accompanied by ominous pyrotechnics on the screen.)

2. The system was to have a nonstructure. "Transparent" in the sense of Oettinger and Marks,* it would provide an unaffected view into structures of any character which resided as data within the system. All length and size problems were to be overridden, with the user uninformed of storage breaks in the material or where what parts were stored. Indeed, the different memory levels of core, disk, and tape were to be treated as a seamless whole by the system program, with automatic shipping and swapping as required. (This is now called "virtual memory," although the term has acquired technical meanings which are not quite relevant.)

3. The system was to be psychologically oriented to whatever task was at hand, without confusing technicalities from another realm (a previous program, or unexplained system features) hanging around to confuse the user. More subtly, the *atmosphere* of the console was to be changeable by various means to make it feel like the place to be doing what you were doing. Button-overlays do not go nearly far enough. A variety of cues, including color, button shapes, and decorative embellishment of the screen, must be delicately crafted. If we seek to create an orientational and conceptual world for the user, both the unification and aesthetics of this world are of supreme importance.

4. The system was to be smoothly adapted for text reading, writing, and editing, with the simplicity and fail-safe qualities I have spoken of. I mean "text" in the larger sense, including hypertexts.

5. A nonnumerical indexing mechanism was to allow one sequence of text to provide an index into another piece of text. This could be not only an ordinary table of contents, but a digest, commentary, or other collateral structure or version.

6. The system was to allow users to consider and compare alternate versions and arrangements of the same material, stored simultaneously and interconnectedly. Any versions could be changed and worked on, with their interconnections and correspondences maintained automatically.

7. A historical trail feature, plus a backtracking mechanism, would permit a user to travel backward in time through earlier versions and stages of his writings, or his other work and considerations, at the scope. Correspondences among such things would be maintained automatically through the parallel and alternative mechanisms already mentioned. Moreover, by returning to an earlier version and making changes to it, he could retroact with his work, pursuing alternatives earlier foregone and initiating evolutionary forks from a previous time. The object of this facility is not to burden the user with peculiar options, but to help him explore more swiftly the possible pathways for developing his ideas and work that would ordinarily be foreclosed to him.

8. Finally, the system was to be beautiful, and its use a continual pleasure.

So much for the external specifications. How to do all this inside is another problem. Five years ago I didn't know much about certain important things. With cantankerous faith I blundered on.

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*Anthony G. Oettinger, with Sema Marks, *Run, Computer, Run: The Myth of Educational Innovation*, Harvard University, 1969, p. 19.

COLLATERAL DATA STRUCTURES

First I recognized that a certain relationship was essential and basic. I have called it different things at different times, "zipper list" being the simplest. The idea is that two lists, or structures, have their corresponding parts noted in the data structure, without regard to the relative sequence of their parts. A zipper-list facility would permit such relationships to be taken note of and kept tract of, despite other developments in the file.

Now, computer people I talked to thought this was a pretty stupid thing to be bothering with, especially since in the glorious realms of list processing you are allowed to tie your data in knots every whichway. Why bother with monogamous one-for-one links when list processing gives you orgies? Yet this is precisely the relation I think is most basic for tasks of creative consideration, although there are many variations. If two things have corresponding parts, whether they are symphonies or machines or individual drafts of some particular book, we need some way to notate these correspondences for computer storage. An item-for-item parallel listing structure is therefore appropriate.

What to call these things is puzzling. Parallel lists? "Parallel" has difficult connotations. "Zipper list" is not bad when the sequence of elements is significant. But when we are talking about correspondences between knotty wholes, such as machines or philosophies, we need a nonsequential term. The term "collateral structures" seems both sufficiently expressive and neutral. I define two data structures as *collateral* if at least one has some sort of private integrity, and the other holds information relevant to it.

The more I thought about collateral data structures, the more interesting they became. First there was the idea of looking up textual parts of one thing by corresponding textual parts of another—a zipper-list pair. Then there was the idea of having alternative versions of the same thing, whose correspondences are kept tract of. More zipper lists. Moreover, the indexing of a list by a list can be extended indefinitely.

Another lead appeared. It might be very useful to have pure text stored in one stream, without codes or irregularities outside the character set, and have its formatting and indexing in other streams. Parallel pointers from outside differentiate the data. More zipper lists. Indeed, it could be useful for many nontextual purposes to store data in one stream and related metadata in another— "a little something on the side."

These different leads seemed to be converging.

Another feeling I had was that there was something basically wrong with the way displays were being programmed and designed. Sutherland's original Sketchpad program seemed to have been set in concrete in the design of various machines, on top of which the conventions of input and output provided many, you will excuse the pun, stumbling blocks. We seem to require *n* buffers, all different; various stacks of niggling errands; and still attention from a main computer. It seemed to me that there must be some way to simplify things.

OPULENCE

There is no time to discuss here the way this has worked itself out, but the comeuppance has been a rather unusual system design, now ready for implementation. Out of the original desiderata has come an unusual underlying set of structures, conventions, and peculiarly integrated design tricks.

Built around a minicomputer, it should permit the animation of dynamic display without flicker, even as the data rolls or changes; the definition of indefinitely many hypertext types and *connections;* and ways of defining new windows into mind-space. In other words, an opulent input-output machine, sufficient for the richest user activities we may want to program. Its main purpose is to let us create, write, and experience more knowingly, and wander freely through the multidimensional realms of hypertext and hypergrams. But it is hoped that the fundamental design may be extended to provide windows into mind-space of any complexity.

END

If we are to move toward anyone's computopia, or even the simpler goal of a more human and humane world in which computers are prominent, what experts call technically necessary will have to come under close public scrutiny.

Doubletalk and silly press releases have done their damage. The public has been told what experts think the computer should do to them; now the public is down on computers and, by these lights, rightly. It is time for a new accommodation.

And we who have known enough to do so will have to stop fooling the public. To insiders, the computer is not just a tool, but a costume we wear when we want to further our own ways of doing things, much as Bugs Bunny masquerades as a tiptoeing treetrunk. We have gotten away with this long enough. Ordinary people will have to learn enough about computers to evaluate technical assumptions critically, as they already are in the politics of automobiles and garbage.

Computer teaching is an area ripe for public understanding. I suggest that such understanding should begin, not with contemplation of rigidified and sequenced systems, but with an appreciation of the playgrounds and wonderlands for the mind that may now be created. Later we can find what methods of presentation are best, *if any* may be called "best"; but people must understand first the magnificence of computer display and where it can lead.

A sense of awe is essential to work in this area. If there is a failure of awe, you do not understand computer display.

And perhaps that says something about education. For awe and understanding to occur at the same moment is perhaps the pinnacle of the human experience. It is certainly the most important moment of education, if it ever occurs. The two sides of the mind, feeling and insight, are no more separate than the two sides of a coin. Both must be served. Both must act together. How the person feels at the console largely determines what he will learn for good.

I believe one university built in the thirties had a skyscraper called the Cathedral of Learning. That doesn't put it badly. If a cathedral is a place of awe and communion, then our new cathedrals of learning will be our presenting and responding consoles. The architecture of these consoles, and the crafting of their responsiveness and their virtual spaces, is a worthy task.

Starting from general concerns, I have tried briefly to explain one man's obsessions and pursuits, tied together as interconnected ideas rather than merely as an enumerated list. I propose two general solutions for a lot of problems: hypertexts for teaching, "information retrieval," and ordinary reading and writing; and, at a very different level, revised programming structures to break the input-output bottleneck for small display computers. But I do not claim that these approaches have unique technical imperative or divinely inspired epistemological virtue. Or that they are the only things worth doing. They are simply among the many, many things that should be tried. To claim otherwise would really be cybercrud.

CENTRAL COMPUTER CENTER ORGANIZATIONS AND COMPUTER SYSTEMS: OPTIONS FOR INSTITUTIONS OF HIGHER EDUCATION

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INTRODUCTION

A recent issue of *Computer Characteristics Review* listed over 200 computer systems which are produced by U.S. companies and numerous models and configurations of models are available for each. There are literally thousands of different combinations available from U.S. companies alone. Monthly lease on these systems ranges from a few hundred dollars per month to nearly a quarter of a million dollars per month. Their purchase prices range from a few thousand dollars to more than ten million dollars. We could say that there is a computer system to fit any budget; however, it is more appropriate to say that for any mission in any type of organization there is a computer system available. Indeed, there will usually be several systems from which to choose.

Computer selection procedures for institutions of higher education should be based upon what is expected of the facility, which in turn is dependent upon the nature of the organization which it is to serve. There are many alternatives available. The placement of the computer in the institution should have the attention of the very top administrative officials. The policy decisions with regard to the role that the computer is to play in the institution should be made by them. Many factors must be taken into consideration in making these policy decisions. One obvious characteristic of institutions of higher education, which seems to stand out with regard to computer-center organization and computer requirements, is the size of the student body. Enrollment in the following classes of institutions will be discussed: less than 2,500 students; 2,500 to 5,000; 5,000 to 20,000; and greater than 20,000. Of course, there are exceptions in that some specialized institutions, such as medical schools and technological institutes, may need to be considered separately.

In other words, other factors, such as research and instructional needs, can carry more weight than mere student size.

In the discussion that follows, the computer systems are classified according to costs expressed in monthly rentals (see Table 1).

Table 1

COMPUTER SYSTEM CLASSIFICATION BY COSTS

Computer Size	*Monthly Rental*
Mini	Under $1,200
Small	$1,200 – $5,000
Medium	$5,000 – $40,000
Large	$30,000 – $150,000

Operating costs for the centers are estimated as follows: for time-sharing terminals, remote batch, minicomputers, and small computers cost estimates are based on data from experiments being conducted with NSF support by the Southern Regional Education Board and several large universities. Estimates for medium- and large-scale computer systems are based on Fig. 1, which contains data published in an article by Dr. Martin B. Solomon in *Datamation*, March 1970, "Economies of Scale and Computer Personnel." Staff costs are estimated from the graph and approximately ten percent is added for other costs. In each case the rental cost is obtained from the upper and lower end of the range for that classification unless otherwise specified.

OPTIONS FOR INSTITUTIONS WITH UNDER 2,500 STUDENTS

Institutions with under 2,500 students will find it very difficult to justify separate computer facilities for administrative uses, and those with under 1,500 may not be able to justify use of the computer at all for administrative purposes. The smallest institutions located in large metropolitan areas might wish to have certain administrative data-processing tasks performed by so-called "service bureau" operations or may carry their data and programs to a nearby university or business computer center for processing. Options 1 to 4 (see Table 2) do not lend themselves to administrative uses; however, under option 5, if the minicomputer has disk storage and a line printer, it may well be used for administrative data-processing tasks. However, it will need to be supplemented by a few pieces of punched-card equipment. Option 6 should be quite useful for administrative data processing. In fact in both options 5 and 6 the possibility of administrative use might be necessary to justify these options. In each case it is assumed that the person responsible for the center will report to a high position in the academic administration. As a general principle, the

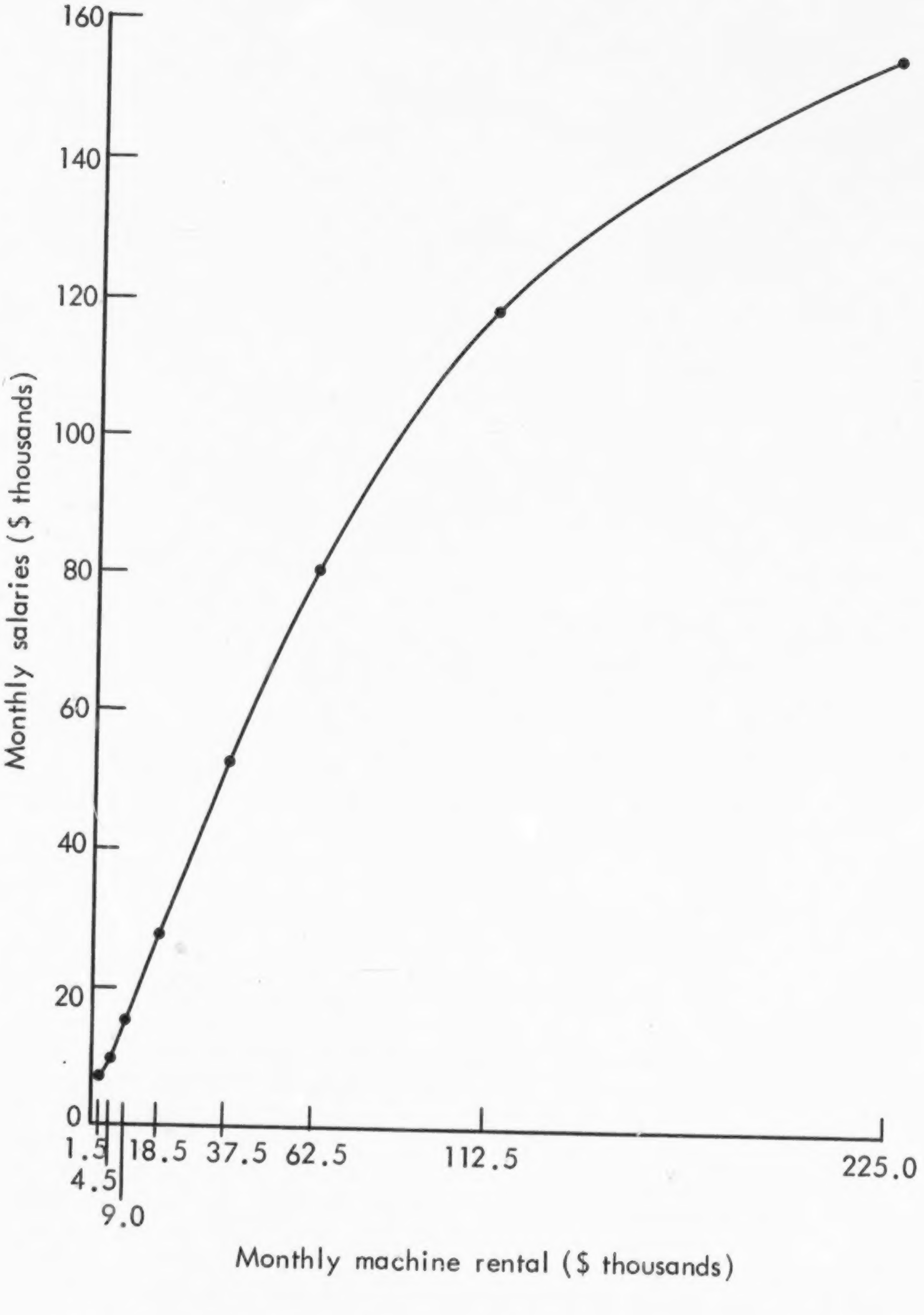

Fig. 1—Costs for medium, and large-scale computer systems

Source: Martin B. Solomon, "Economies of Scale and Computer Personnel", Datamation, March, 1970, pp.107-110.

Table 2

SOME OPTIONS AVAILABLE TO INSTITUTIONS WITH UNDER 2,500 STUDENTS

Option	Function(s)	No. of Centers	Type of Facility	Annual Operating Costs[a] ($ thousands)
1	Instruction, some research	1	1 T/S terminal	5 - 15
2	Instruction, some research	1	Minicomputer T/S or batch	10 - 15
3	Instruction, some research	1	2 T/S terminals	15 - 30
4	Instruction, some research	1	Minicomputer T/S	15 - 30
5	Instruction, research, administration	1	Minicomputer Batch (disk and line printer)	20 - 40
6	Instruction, research, administration	1	Remote batch terminal	30 - 40

[a] Does not include systems analysis and programming for administrative uses.

director or head of the center should report to a position equal to or higher than the head of any division which the center serves. For this class of institution centralization of hardware is a must. Administrative offices desiring to use the computer facilities should provide their own systems analysis and programming personnel. A schedule of operations or a priority system should be established by high levels of the administration. This responsibility should not be forced upon the director or head of the center. The center should be located where round-the-clock access can be made available when needed. When usage approaches two full shifts, 352 hours per month, of efficient usage, expansion of the facility must be planned within 18 months to two years or scheduling will become difficult, a tight set of priorities will become necessary, and users will become irritated. A reasonable guide to usage growth is one full shift, 176 hours per month, after 18 months of operation; two full shifts, 352 hours per month, at the end of three years; and three full shifts at the end of five years. A usage rate lower than this would indicate that the system may be too large for the institution's needs. On the other hand, a usage rate which is faster would indicate that a system was probably too small. In all cases it is assumed that there are available one or more compiler or problem-oriented languages, such as BASIC, FORTRAN, ALGOL, PL-1, etc., for instruction and research use. Although certain administrative tasks can be performed with these languages, COBOL or a report-program-generator-type language is usually of more general utility.

OPTIONS FOR INSTITUTIONS WITH 2,500 TO 5,000 STUDENTS

Table 3 presents four options for this class of institution. In this group, administrative uses play a more important role in the selection of the computer(s). Smaller institutions might well share a remote batch terminal which is essentially option 6 of Table 2. As the load builds up, a second remote batch terminal might be necessary to handle the administration alone, while the other is used for instruction and research or option 8. If communications costs are significant, the institution might well consider a small computer instead. The choice between options 8 and 9 will depend upon the philosophy of the administration and the extent of the need for a "larger" small computer. As usage grows there is a tendency for the applications to require faster throughput, larger storage, etc. In general, a computer system leasing for 2X dollars per month is more powerful than two computers renting for X dollars per month each.

However, special attention must be given to the organization of such a center. The director of the center must report to the top administration, that is, the president or vice president. The systems analysis and programming for administrative applications can either be centralized or diffused among various administrative departments. Unless there is a central ongoing activity related to, say, management information systems development, then it is probably best to let each administrative department develop its own system to the extent possible, i.e., do their own systems analysis and programming. This is particularly true when only one or two of the administrative departments have interest in using the computer. Where many administrative departments are planning to use the computer, a central administrative systems-analysis and programming staff can be more efficient and less costly. Under option 8, if two separate small computer facilities are maintained, duplicate systems-progamming staffs will be required. Although this function can usually be served by one person, in the case of the small computer the savings of one systems progammer may be obtained by using option 9 or one "larger" small computer. For the larger institutions in this group, option 10 would be required, that is, a medium-sized computer. Such institutions are more likely to have heavy research requirements as well as greater administrative requirements. Instructional use alone is not likely to require a computer of this size. In this case, instructional use becomes filler for a system required for research and administration. There are exceptions, of course—for example, institutions which have a degree program in computer science, data processing, etc. Throughout these discussions instructional uses refer to the use of the computer in *instruction about computers* and using the computer in instruction as a *computational or information-processing* tool. Uses of the computer as an instructional device are not included, i.e., CAI.

OPTIONS FOR INSTITUTIONS WITH 5,000 TO 20,000 STUDENTS

This group of institutions includes most of our state universities. Although these institutions may have some dedicated computer facilities for research or instruction, in general there are two basic options: option 11a, a separate facility for instruction and research consisting of a medium computer; and 11b, a separate center for administrative uses with a medium computer (see Table 4). The economies

Table 3

SOME OPTIONS AVAILABLE TO INSTITUTIONS WITH 2,500 TO 5,000 STUDENTS

Option	Function(s)	No. of Centers	Type of Facility	Annual Operating Costs/Center[a] ($ thousands)	Annual Operating Costs/Institutions[a] ($ thousands)
7	Instruction, research, administration	1	Remote batch terminal	40 - 50	30 - 50
8a,b	Instruction, research, administration	2	Small computer or remote batch	30 - 75	60 - 150
9	Instruction, research, administration	1	Small computer	40 - 100	40 - 100
10	Instruction, research, administration	1	Medium computer[b]	200 - 700	200 - 700

[a] Does not include systems analysis and programming for administrative uses.

[b] $5,000 to $20,000 per month.

Table 4

SOME OPTIONS AVAILABLE TO INSTITUTIONS WITH 5,000 TO 20,000 STUDENTS

Option	Function(s)	No. of Centers	Type of Facility	Annual Operating Costs/Center ($ thousands)	Annual Operating Costs/Institution ($ thousands)
11a	Instruction, research	2	Medium computer	200 - 1,300	400 - 2,600
11b	Administration	2	Medium computer	200 - 1,300	400 - 2,600
12	Instruction, research administration	1	Large computer[a]	960 - 1,800	960 - 1,800

[a] $30,000 to $60,000 per month.

of scale become even more significant when we are dealing with machines of this size. It is possible that an institution might only need two small-medium computers, i.e., at the lower end of the range; however, as time goes on and usage builds up the small-mediums become medium-mediums and then large-mediums. Our comments relative to centralization of hardware for the previous group of institutions now become true "in spades." Medium to large-medium computers require from three to five full-time systems programmers each. Option 12, a single large computer, not only provides more power availability, i.e., can handle larger problems, but can also be operated with less than twice the staff needed for a medium computer installation. In option 12 we are really talking about "small" large computers or a range of $30,000 to $60,000 per month rental. Option 12 has a real savings potential but requires careful consideration with regard to organization. Figures 2, 3, and 4 contain organization charts for the University of Alabama, the University of Kentucky, and Oklahoma State University, respectively. These institutions have moved in this direction, i.e., from option 11 to option 12, in the past few years. Computer systems of this size can be equipped for communications handling capability. An institution having an occasional need for a large computer but yet unable to justify it for their own purposes may wish to supply remote batch terminals or time-sharing terminals to nearby institutions. This has become quite a common practice; in particular, the NSF has made grants to 15 to 20 such installations for this purpose.

OPTIONS FOR INSTITUTIONS WITH OVER 20,000 STUDENTS

In this class of institutions the doctoral-granting ones are of primary interest. The needs of the non-doctoral-granting institutions in this class will tend to be closer to those of the "5,000 to 20,000" groups of institutions. The doctoral-granting institutions in this class are characterized by:

1. Very complex administrative structures.
2. Extensive and intensive research projects.
3. Large numbers of graduate students, particularly at the doctoral level.
4. Doctoral programs in computer sciences, information sciences, etc.

All of the above place heavy demands upon a computer system and the computer center organization. Dedicated and special-purpose computers abound on these campuses. Many of them are purchased with special grants funds and are usually in the mini and small class. Such facilities can have an important role in providing supplemental or special computing and control functions in the research and instruction programs of these large institutions. However, uncontrolled acquisition of these small computers can dissipate the resources of the institution and prevent the acquisition and/or proper support required for the large computer systems which must be available for large research problems.

Three options are given in Table 5 for the largest doctoral-granting institutions. Option 13 is essentially option 12 expanded to include larger computer system possibilities. Most of these institutions have sufficient research and instruction needs to justify a large computer dedicated to these uses. Furthermore, the requirements for administrative data processing and management information systems are

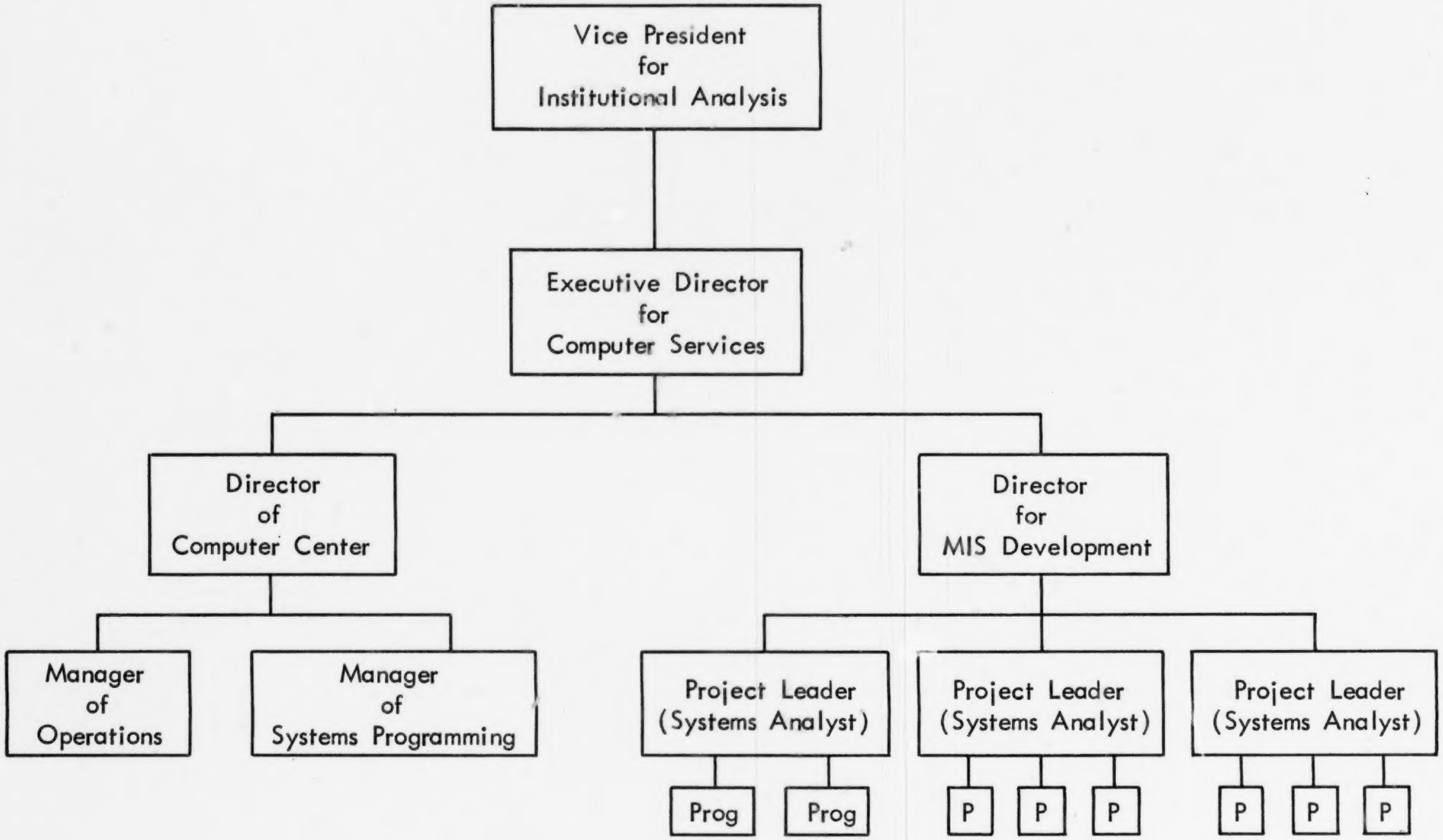
Vice President
for
Institutional Analysis
Executive Director
for
Computer Services
Director
of
Computer Center
Director
for
MIS Development
Manager
of
Operations
Manager
of
Systems Programming
Project Leader
(Systems Analyst)
Prog
Prog
Project Leader
(Systems Analyst)
P
P
P
Project Leader
(Systems Analyst)
P
P
P

Fig. 2—The Computer Center in the Administrative Hierarchy: University of Alabama

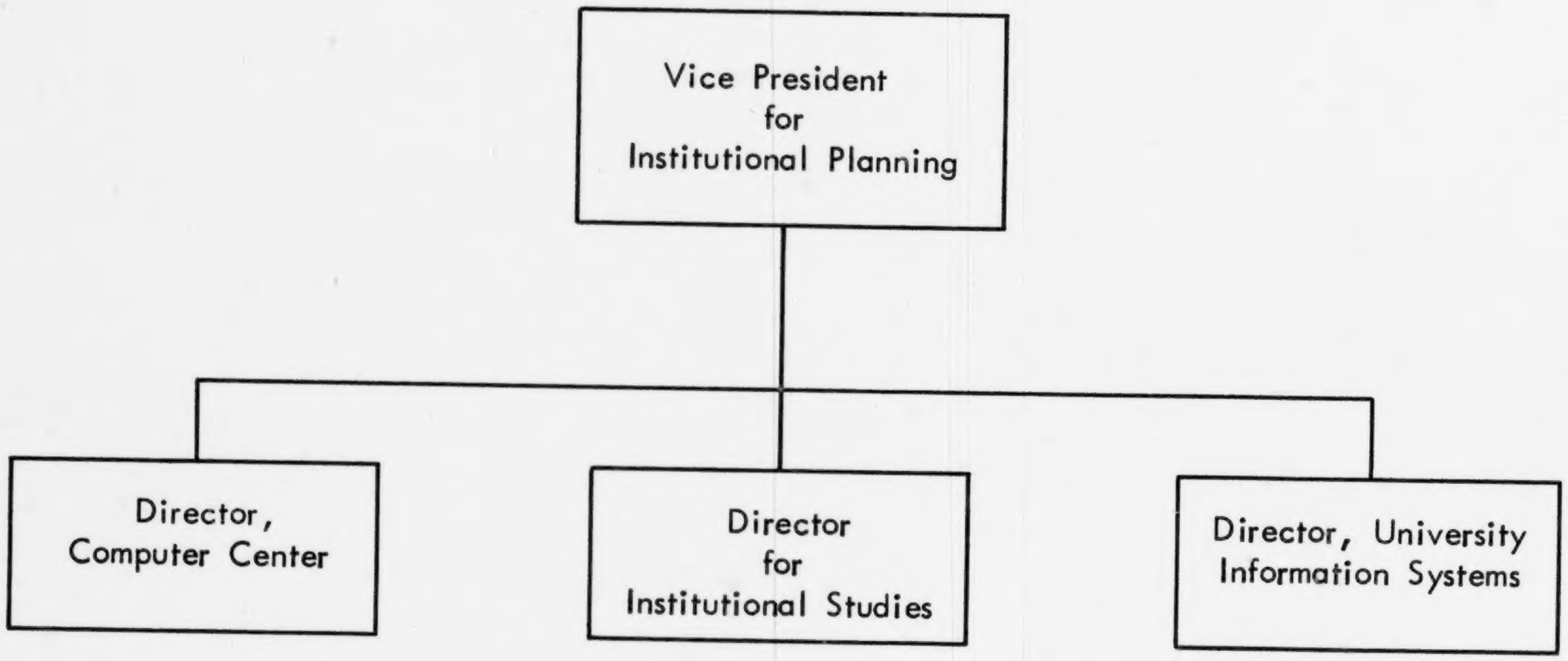
Vice President
for
Institutional Planning
Director,
Computer Center
Director
for
Institutional Studies
Director, University
Information Systems

Fig. 3—The Computer Center in the Administrative Hierarchy: University of Kentucky

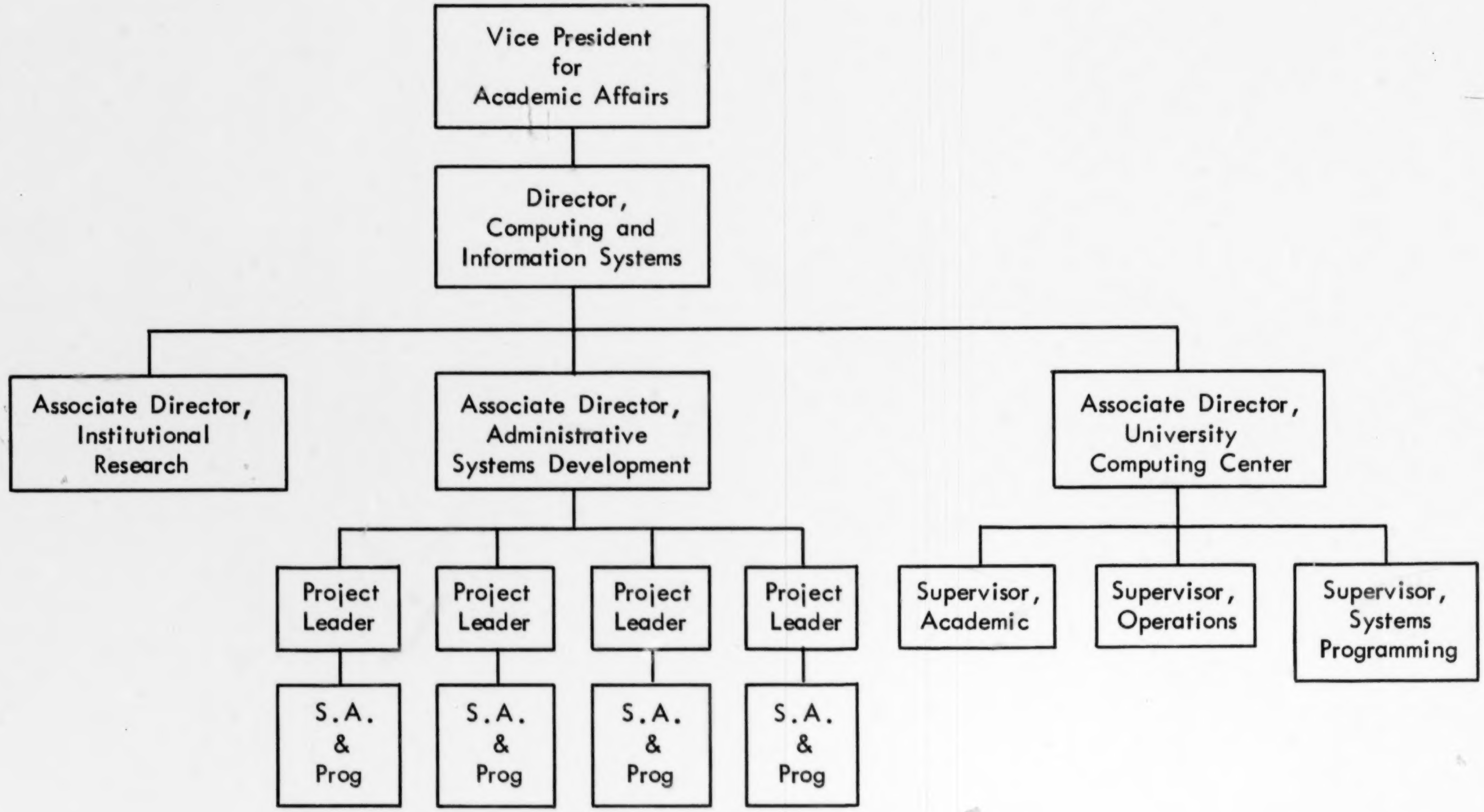
Vice President
for
Academic Affairs
Director,
Computing and
Information Systems
Associate Director,
Institutional
Research
Associate Director,
Administrative
Systems Development
Associate Director,
University
Computing Center
Project Leader
Project Leader
Project Leader
Project Leader
S.A. & Prog
S.A. & Prog
S.A. & Prog
S.A. & Prog
Supervisor,
Academic
Supervisor,
Operations
Supervisor,
Systems
Programming

Fig. 4—The Computer Center in the Administrative Hierarchy: Oklahoma State University

Table 5

SOME OPTIONS AVAILABLE TO INSTITUTIONS WITH OVER 20,000 STUDENTS

Option	Function(s)	No. of Centers	Type of Facility	Annual Operating Costs/Center ($ thousands)	Annual Operating Costs/Institution ($ thousands)
13	Instruction, research, administration	1	Large computer	960 - 3,720	960 - 3,720
14a	Instruction, research	2	Large computer	960 - 3,720	1,920 - 7,440
14b	Administration	2	Large computer	960 - 3,720	1,920 - 7,440
15a	Instruction	3	Large computer	960 - 3,720	2,880 - 11,160
15b	Research	3	Large computer	960 - 3,720	2,880 - 11,160
15c	Administration	3	Large computer	960 - 3,720	2,880 - 11,160

enough to tax a large computer system and its center organization at these institutions. The associated logistics related to the design and maintenance of the data and information systems, the channeling of the inputs and outputs, and the creation and maintenance of huge data bases are sufficiently complex to challenge the best center organizations. Hence those institutions operating under option 13 will rapidly move to option 14, that is, to a large computer for research and instruction and a separate large computer for the administrative data processing and management information system.

If the growth rates which those institutions have known during the past decade continue through the 70s, and the uses of the computer in instruction become more extensive and intensive as is expected, then option 14 will become commonplace in the largest institutions. A large computer facility will be required for each of these functions: instruction, research, and administration.

AN ESTIMATED DISTRIBUTION OF COMPUTER CENTER INSTALLATIONS BY FUNCTIONS SERVED

An estimated 980 of the 2,477 institutions of higher education had at least one computer by June 30, 1967. By June 30, 1969, 1,255 of the then 2,537 institutions were expected to have access to at least one computer.

Eight hundred ninety-one institutions reported 1,106 administratively independent installations in 1967. Approximately 900 of these installations had some kind of computer. For each computer in each installation the proportion (in fifths) of the total utilization was reported for research, instruction, administration, and other. The title of the position to which the head of each installation reported was also given and coded. The initial coding was done on the basis of 36 classes of titles. The installations with computers were separated into six groups as follows:

1. All computers in the installation were used for research only.
2. All computers in the installation were used for instruction only.
3. All computers in the installation were used for administration only.
4. At least one computer was used for both research and instruction but none for administration.
5. At least one computer was used for research and/or instruction and administration.
6. Other (usually machines not yet installed or at least not long enough for usage to be reported).

Figure 5 shows the distribution of the types of installations according to the six categories above and by public and private institutions. From the chart we see that there are no obvious differences in the overall distribution of types of installations between those in public institutions and those in private colleges and universities.

For Fig. 6 the types of installations were divided into three groups:

1. No administrative uses
2. Administrative use as well as research and instruction
3. Administrative use only

and the titles of the offices to which the head of the installation reported were reduced to seven general titles:

1. President (or head of institution)
2. Chief Business Officer
3. Chief Academic Officer
4. Dean
5. Research Officer
6. Engineering Dean
7. Institutional Research Officer

From the chart we see that there are no obvious differences between public and private installations with regard to the position of the computing installation director in the administrative hierarchy.

COMPUTER CENTER ORGANIZATIONS TO SERVE MANY INSTITUTIONS

Computer systems can be shared by several institutions through several different administrative organizations, such as:

1. Commercial time-sharing companies (100 or more available)
2. Through a consortium for member institutions (Associated Colleges of Central Kansas, Atlanta University Center Corporation)
3. A center operated by a single college or university (several)
4. A center operated by a separate nonprofit organization (Triangle Universities Computation Center and Middle-Atlantic Educational and Research Center)

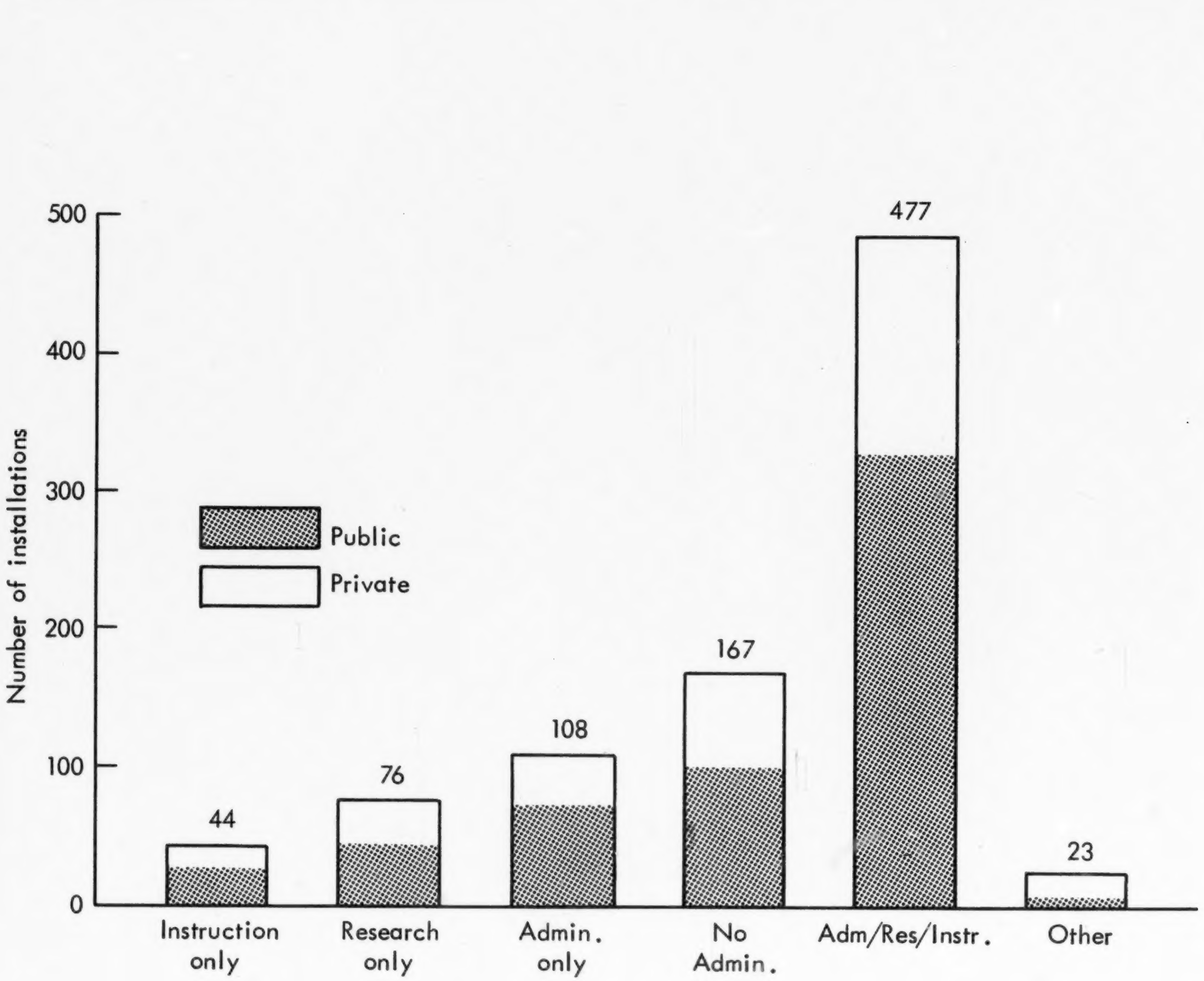

Fig. 5—Computer installations by type and usage (895 institutions reported, June 30, 1967)

Source: Inventory of Computers in U.S. Higher Education, Computer Sciences Project, Southern Regional Education Board, National Science Foundation Contracts NSF C 508, 604, June 30, 1967.

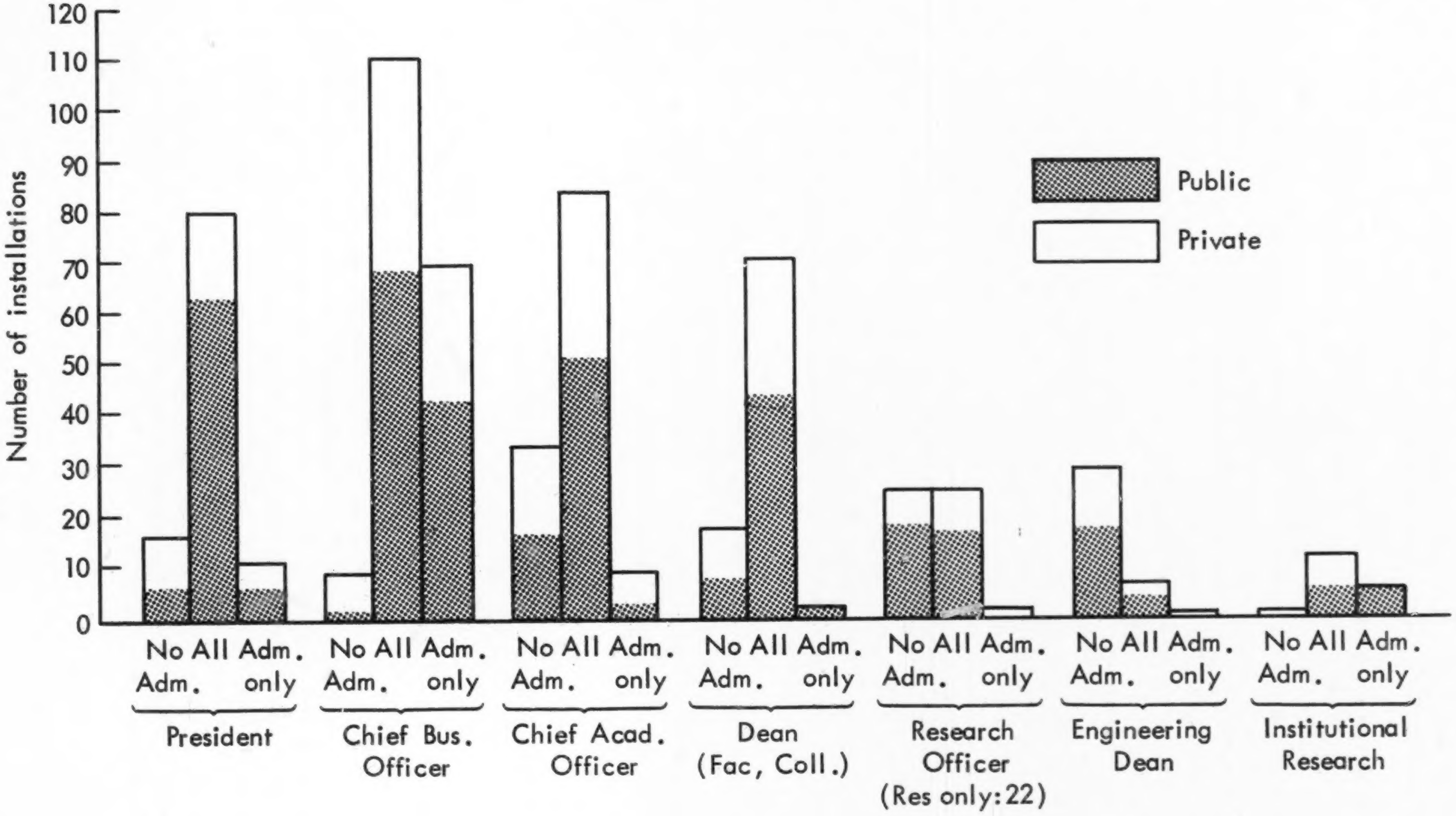

Fig. 6—Title of officer to whom head of computer installation reports by type of usage of center

Source: Inventory of Computers in U.S. Higher Education, Computer Sciences Project, Southern Regional Education Board, National Science Foundation Contracts NSF C 508, 604, June 30, 1967.

5. Third parties (New England Regional Computing Program, North Carolina Education Computing Service)

With the exception of (2) above (ACCK and AUCC), all of the above organizations utilize computer communications systems. For the most part the communication lines are "voice grade" lines. The ACCK operates a courier service and AUCC students walk to the computer center from five adjacent campuses.

Although the term "computer network" is used freely in referring to these "computer-communication" systems, none of them are true computer networks insofar as hardware is concerned. However, if the intercommunication which results among the users is taken into consideration, all such cooperative computing enterprises can be called networks.

The trend at present is toward cooperative uses of computer hardware. The recent introduction of a multitude of mini and very small computers may slow this trend. The small college seeking computer facilities for instructional uses has many more options available to choose from than it did only two years ago.

STATEWIDE AND REGIONAL PLANNING FOR COMPUTER FACILITIES

The EIN efforts of EDUCOM, the Computer Sciences Project of the SREB, NERCOMP, and the ARPA Network are examples of regional cooperation in the planning and/or utilization of computer systems.

State coordinating agencies, councils, or boards for higher education in Virginia and Georgia are active in the planning and acquisition of computer systems for institutions under their jurisdiction. There are similar activities at various stages of implementation or study in South Carolina, Maryland, Florida, Louisiana, Texas, West Virginia, New York, New Hampshire, and possibly in several other states.

PURCHASE VERSUS LEASE FOR COMPUTER SYSTEMS

Fears of obsolescence and "growing out of" earlier computer systems have caused the institutions of higher education to favor leasing the equipment rather than purchasing it. State institutions are still handicapped with regard to purchase because of the way in which capital funds are controlled and because in most cases they cannot engage in long-term (more than one year) financing agreements. Many of the large state universities have nonprofit foundations which are closely affiliated yet are not a part of the institution. Such foundations can engage in long-term financing and can purchase a computer which they in turn can lease to the university. Oklahoma State University recently used this method to obtain an IBM 360/65 system. Savings to Oklahoma State averaging $100,000 per year for the next five years will result from this method of leasing. Institutions of higher education should carefully examine the alternatives with regard to purchase and lease before acquiring a computer system.

PROBLEMS ASSOCIATED WITH COMPUTING NEEDS IN HIGHER EDUCATION

Problems encountered in the management of computer services today in higher education are not due to lack of hardware technology. Problems with vendors' software have diminished, but there is still a shortage of systems programmers. The real problems encountered today with regard to computers in higher education are *people:*

1. There are not enough *people* with experience in managing the large, complex computer systems.
2. Too few administrators (people) understand the staffing requirements for computer systems of all sizes. This seems to be particularly true with respect to programming requirements. Much of this lack of appreciation is due to the "oversell" which has been experienced with respect to computer hardware.
3. Administrators have been reluctant to reassign priorities and responsibilities and reallocate resources to provide for the proper computer organization and its support.
4. Faculty have been relatively slow in taking advantage of the computer to improve their research and instruction whenever possible.
5. Salary scales for computer center personnel, particularly in the programming areas, have not been competitive.

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COMPUTERS IN INSTRUCTION: A COMMENTARY WITH RECOMMENDATIONS

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The conference on *Computers in Instruction: Their Future for Higher Education* has cited many of the issues and problems relating to this new technology: some of the concerns and issues articulated related to costs and capabilities, facilities and supplies, and implications. A key issue which has never been publicly pursued in serious detail concerns the *organization and development of professionalism relating to this technology.* This issue is perhaps central to any orderly development and progress in this area. The issue clearly cannot be separated from those already discussed at the conference. Yet in this paper I attempt to develop and highlight a few auxiliary issues not covered there; thus I intend to avoid needless duplication of viewpoint.

Recommendations are included with the commentary throughout. Most of the recommendations can be implemented without incurring major costs. Many of them can be implemented at the local level, circumventing national and political considerations.

The issue of professionalism has a very clear basis. Most schools, colleges, and universities that train and develop professionals are departmentalized and compartmentalized. The institutional structure is usually designed to accommodate discipline studies relating to professional needs. Professionalism based largely on new technologies, particularly those manifestly multidisciplined technologies, often falter because the academic institutional structure frequently does not accommodate interdisciplinary developments. These accommodations are required in order to attract internal and external respect, and to "flush out" the reals from the pretenders. Examples of these technologies include ecology and environmental sciences, computers in education, mathematical studies of educational processes, consumer protection, computers in the social and behavioral sciences, and medical engineering. These examples are not intended to be definitive. Yet they do demonstrate the range of the technologies—from the "soft" technology to the "hard" technology.

A recent trend on some campuses seems to be the "you name it, we add it" philosophy of introducing academic departments. The problems this poses are astounding. Some of the obvious considerations are faculty, financing, facilities, accreditation methods for appraising progress, prestige and competence, and tenure (departmental duration). There is a need for this flexibility for adding new departments. I suggest, however, that this prerogative has been abused. The first recommendation should reduce these abuses of adding departments indiscriminately. It is that *academic institutions define formal institutional procedures—well publicized and promoted in official institutional documents—for permitting student-designed or "student-initiated" academic programs as independent and individual academic specializations.* The recommendation therefore encourages individual "majors" without formalizing departmental structures. It is further recommended that *students be permitted to pursue these individual academic programs by either of the following arrangements:*

1. *Students select faculty advisors from among local faculty. These advisors would be responsible for developing and underwriting the students' academic program. A minimum of three such advisors is thought advisable.*
2. *Students shall be permitted and encouraged to participate in or define and solicit support for project-oriented research. This research should be conducted at the home institution or at some affiliated institution (e.g., a nonprofit research organization). Official documents of universities and colleges should publicize and promote projects in progress at the institution and at its affiliated institutions.*

The point of these recommendations should be obvious. They seek to formalize a flexible institutional policy that permits relevant technological problems to be studied. They also seek to encourage *all* students to consider developing their own educational and professional experiences. (The word *all* is emphasized with good reason: It is far too often that the student who is less inclined to challenge the disciplined academic system compromises his aims and possible competencies. The student who presently takes advantage of individually defined programs is usually adept in academic politics—a requirement that need not exist and certainly should not be exclusionary.)

It should be noted that many universities and colleges have the underlying structural machinery laid for implementing the above recommendations. They usually falter in two aspects, though. The first is that the procedures and machinery are not well publicized and are not generally accessible to the curious student—much less the naive student. Another aspect is that faculty members are usually uninformed or, at best poorly informed as to procedures and prerogatives. *It is therefore an institutional responsibility to adequately inform its clients of available procedural machinery. The institution must also inform its constituents of the reasons that these procedures are present.*

The second alternative above deserves further discussion. It is the intent that one or more academic institutions become affiliated with independent, nonprofit research and development institutions and other nonprofit, nonteaching institutions. This would permit students to gain valuable experiences by interacting with highly qualified, nonteaching professionals—some of whom may play a direct part in supervising the students' progress. It may also permit the student to gain access to valuable equipment or other technological advances. It might also provide a reasonable source of financial aid to the student.

The student is the object of the above discussion for *only* one reason. It is that all future professionals will have once been students. The aim is thus to attack the professionalism where it is actually seeded.

When mentioning the student one must consider what is required of and for him. A most obvious is the financing of his instructional needs—both salary and instruction. "High-cost" technologies, such as the computers in instruction, require careful examination of this issue, because many of the students' instructional interactions may require costly equipment, or organization, or skills. It seems appropriate to note that *much of the present-day direct financial assistance is funded by foundations and agencies—both inside and outside our various levels of government. This must continue! More funds need to be directly allocated for instruction, however. The host academic institution must also contribute a larger share.* Many computers, for instance, are largely supported by research funds. Their software systems and hardware configurations thereby frequently assume characteristics best suited for the research activities. These characteristics are sometimes incompatible with instructional needs.

There are at least two possibilities which deserve careful scrutiny. Two of these possibilities will be stated as recommendations.

It is first recommended that *universities and colleges give priority and greater weighting to separate research and instructional computing facilities.* The small-scale and medium-scale computers may, in some combination, outweigh a single-source investment in a large-scale computer. It must be recognized that the proclaimed flexibilities of many of the current systems are, in fact, unnecessary restrictions. A *local* network of these small-to-medium-scale computers may be the best solution. *Thus computer scientists would be well advised to perfect the art (and/or science) of networking computers.*

It perhaps is important to observe that most, if not all, of the highly touted computer-assisted instructional centers have a major problem which has not been widely discussed. These centers have flourished because of the significant research and developmental innovations leading to the design of attractive systems and curricula. These developments could not succeed without adequate testing of these new facilities. The testing, however, leads to a production phase. This is especially true when the researcher is conscientious about providing serious and rigorous tests of his results. Unfortunately, the production phase most frequently denies the researcher the opportunity of going back to develop new systems and curricula. At this point the critics enter in droves, failing to concede that more could be accomplished if this dilemma were resolved. Therefore, the researcher interested in pursuing basic research in the various aspects of computer-assisted instruction is cautioned that, again, two or more smaller systems may be better than one. (Note that two or more smaller systems may increase the range of research options too. Parallel-processing CAI systems, for example, becomes a real possibility.)

The term *local network* is used to imply that the network must exist locally —on the same campus. *Local networks seem far more important than large, universal networks such as the ARPA network.* The problems of administration, coordination, transmission errors, and human communication become more manageable.

A second point concerning financing instruction (and student learning by participation) is that *salaries, fellowships, and other stipends must be competitive.* There must not be a large discrepancy between wages paid to students having special skills and persons in other professions who possess comparable skills. In other words, a competent programmer must receive some remuneration for his skills, in order to maintain a high level of interest.

A final point concerning the financing of instruction relates to university and college allocations for instructional usage of computers. We noted earlier that more funding is required. The next requirement is that *all academic disciplines (or multidisciplines) should receive a base allocation—independent of their level of computer usage.* This is needed to develop a wider audience of computer users. It is also needed to further, rather than frustrate, the computer in instruction.

There are two obvious ways for an academic institution to support instructional usage of the computer. One way is to *allocate funds on a "per student" basis. This allocation would be based on the number of credit hours for which the student has enrolled during the quarter.* This should be dynamically scaled according to the computational maturity that the student develops. A second way to support institutional participation is to *allocate funds on a departmental and project basis.* A combination of these is thought to be most appropriate.

Up to this point I have discussed generally the issue of professionalism. Supplemental issues concerning financing and institutional organization have been discussed too. An equally important supplemental issue concerns the quality of the professionals who are to be developed. Certainly all that has been said is aimed at stimulating the development of these "quality" professionals. One further recommendation, however, should remove an important obstacle to this development. It is that *the potential professionals (students) must have a formal involvement in the preparation of their instructional materials.*

This is *not* to conclude that the "blind should lead the blind." To the contrary, those students having been thoroughly exposed to important concepts affecting their interests should be formally involved in developing articulate and enriched materials for those preprofessionals coming after them.

An analogy might be appropriate at this point. Consider the graduate student (or postdoctoral fellow) who has received a rigorous and thorough training in, say, college mathematics. He might be expected to spend a portion of his postbaccalaureate degree studies assisting in the development of instructional materials for the incoming (prebaccalaureate degree) students. It must be noted that many students do have these experiences now; but rarely on a *formal* (institutionalized) basis.

I see several very important reasons for emphasizing this point. First, some of the postgraduate students will be successful, highly acclaimed professionals after exiting from the academic environment. These individuals should be tapped of their various wisdoms when it can be done, and at reasonable costs. Second, because of the time lag required to shake down the student developments, many of the students will have achieved their renown by the time mass distributions are possible—adding to the prestige of their developments.

A third reason is particularly important when the computer is involved in the development or presentation of instructional materials. It is that the time and detail required of a full faculty member in these developments would lead to frustration as well as the poor allocation of his intellectual resources. The student, on the other hand, may be able to effect these developments with the advice and consultation of the faculty. (Throughout the latter discussion I am assuming that the student may or may not receive royalties and authorship for the instructional materials which he has contributed.) Fears that the student is too inexperienced, therefore, can be allayed because of the faculty input.

It might be appropriate to note that the student's contributions may be rewarding in two ways. He may receive remuneration for his services. But more important, if his future lies in an academic environment, he will have received an important experience relating to the art (and science) of teaching. (Most present-day students are thrust into university teaching roles with virtually no background and experience for that task.)

In order to balance the student participation, as well as encourage quality developments, the following is proposed: *Recipients of national fellowships based on competitive scholarship shall be required to commit, say, 5 to 10 hours weekly towards developing instructional materials in their area of specialization.* This should be a condition for acceptance of the fellowship. Thus, fellows such as the NSF, Danforth, and Woodrow Wilson fellows would contribute their skills in developing the educational experiences for their peers. Needless to say, the fellows themselves would be taking this opportunity to review what is assumed to be thoroughly engrained—but often only superficially instilled.

Before leaving the issue of quality one important topic must be mentioned. It is the *need for basic research* concerning the various usages of computers in instruction. This is virtually nonexistent at this stage of developing professionals for this technology. I, therefore, recommend that the National Institute of Education be approved, with that institute contributing to and supporting this basic research (along with its other functions). I also recommend that *a new journal called, say, "Computers in Instruction and Learning," be published. This journal must almost ruthlessly reject papers showing anything less than superior quality and basic research.* While I recognize the difficulties in putting together such a publication, I am confident that it can succeed.

There is one final recommendation that should be stated in the context of my previous comments and recommendations. This concerns the conferral of degrees—and particularly the Ph.D. It has been implied that the computer in instruction, as a technology, will probably remain highly costly. Furthermore, the problems—both basic and applied—which remain to be solved or discussed are far more difficult than one could expect to have discussed in a dissertation developed by a single student. I therefore propose that *academic institutions granting the Ph.D. should institute and formalize procedures for admitting and approving dissertations written by two or more authors—each author being a candidate for that degree.* While some institutions claim to have these procedures, there are far too few of them. Those that do very often do not encourage students to pursue them, and they often impose superficial restrictions such as requiring that each author's contribution be clearly identifiable.

An example might be illustrative: One recent and very encouraging method for studying cognitive and affective processes has been to use the computer to simulate those processes heuristically. Some particular examples are Colby's simulation of psychiatrists and patients, Feigenbaum's simulation of perception and memory, and Smith's simulation of the teaching process. Others can be cited easily. Many of these, if submitted as dissertations, would require disproportionately larger staff and systems effort than a dissertation in, say, mathematics. *They also may require larger and more comprehensive conceptual analysis than the average disserta-*

tion is expected to yield. Yet without the *whole* product, despite all its complexities, the dissertation might not be justifiable, since the controls and constraints might render it useless.

In proposing joint Ph.D.'s it must be clear that the quality of the original and creative work cannot be compromised. At the same time, there should be no demand that each participant's contribution be clearly identifiable. Although the latter obviously must be preferred, I do not wish to destroy or discourage those many efforts that are truly interdependent.